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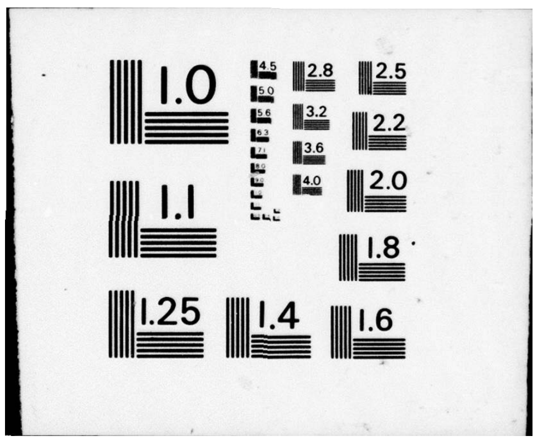
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MISCELLANEOUS PAPER C-70-17

TESTS OF ROCK CORES
WARREN II STUDY AREA, WYOMING

by

K. L. Saucier

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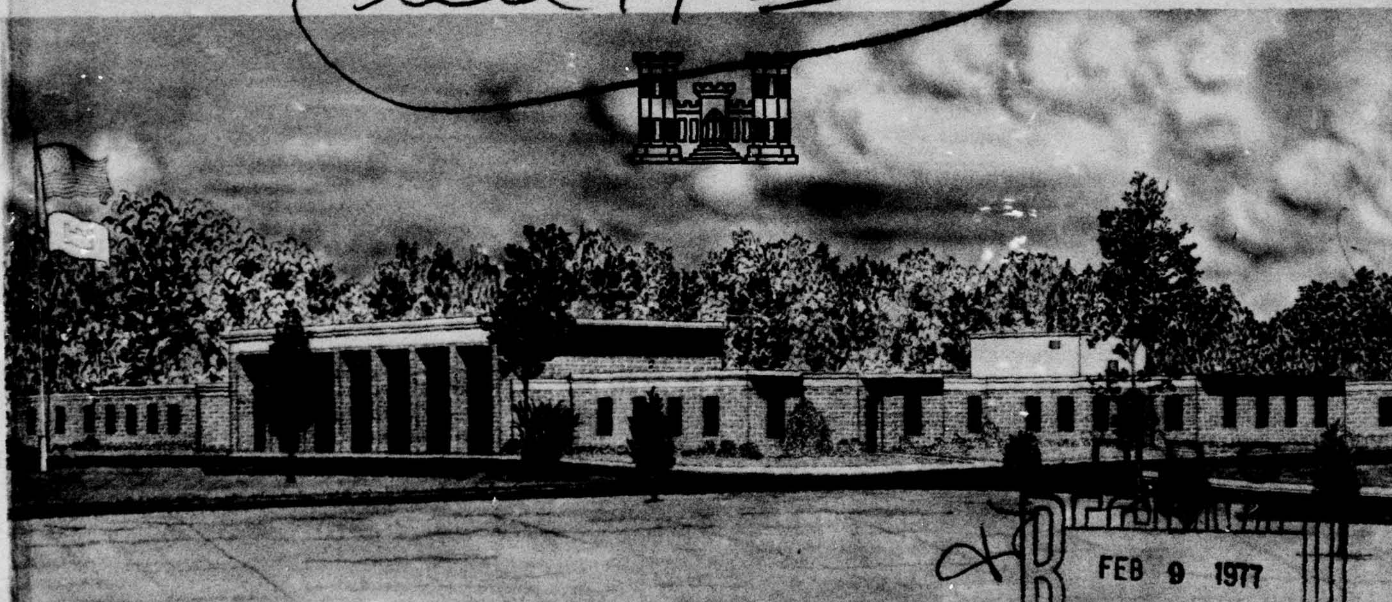

September 1970

Sponsored by Space and Missile Systems Organization, U. S. Air Force Systems Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

ASSOCIATED REPORTS

Report No.	Title	Date
MP C-69-3	Tests of Rock Cores, Warren Area, Wyoming	March 1969
MP C-69-12	Tests of Rock Cores, Mountain Home, Idaho, and Fairchild, Washington, Areas	September 1969
MP C-69-16	Tests of Rock Cores, Castle Study Area, California	October 1969
MP C-70-4	Tests of Rock Cores, Bergstrom Study Area, Texas	February 1970
MP C-70-6	Tests of Rock Cores, Scott Study Area, Missouri	May 1970
MP C-70-7	Tests of Rock Cores, Plattsburgh Study Area, New York	June 1970
MP C-70-9	Tests of Rock Cores, Duluth-Vermillion Study Area, Minnesota	June 1970
MP C-70-10	Tests of Rock Cores, Michigamme Study Area, Michigan	June 1970
MP C-70-11	Tests of Rock Cores, Pease Study Area, New Hampshire	July 1970
MP C-70-14	Tests of Rock Cores, Pembine Study Area, Michigan and Wisconsin	August 1970
MP C-70-16	Tests of Rock Cores, Machias Study Area, Maine	August 1970

MISCELLANEOUS PAPER C-70-17

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ARMY-MRC VICKSBURG, MISS.

ABSTRACT

Laboratory tests were conducted on rock core samples received from five holes from Natrona and Fremont Counties, Wyoming (Warren II Study Area). Results were used to determine the quality and uniformity of the rock to depths of 200 feet below ground surface.

The rock core was petrographically identified as predominantly granite and biotite gneiss. Several specimens of amphibolite gneiss and biotite schist were also identified.

The wide area represented by the five drill holes and the complex nature of the material preclude assessment of the area on a hole-to-hole basis. The overall appearance of the area is one of a complex rock mass with quite variable physical properties. However, based on the limited data available, the area offers possibilities as a competent hard rock medium if poor quality schist can be avoided. Except for the schist, poorer quality rock is predominantly in the upper elevations, but one may expect to remove up to 70 feet of material in some areas before competent rock is reached. A more extensive investigation will be required to identify the most promising hard rock areas.

PREFACE

This study was conducted in the Concrete Division of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Air Force Space and Missile Systems Organization (SAMSO) of the Air Force Systems Command. The study was coordinated with CPT Rupert G. Tart, Jr., SAMSO Project Officer, Norton Air Force Base, California. The work was accomplished during the period August 1969 through May 1970 under the general supervision of Mr. Bryant Mather, Chief, Concrete Division, and under the direct supervision of Messrs. J. M. Polatty, Chief, Engineering Mechanics Branch; W. O. Tynes, Chief, Concrete and Rock Properties Section; and K. L. Saucier, Project Officer. Mr. C. R. Hallford was responsible for the petrographic work. Mr. Saucier performed the majority of the program analysis and prepared this report.

Directors of the WES during the investigation and the preparation and publication of this report were COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows.

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
feet per second	0.3048	meters per second
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms (force) per square centimeter
	6.894757	kilonewtons per square meter
square miles	2.58999	square kilometers

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The purpose of this study was to supplement the information being obtained for the area evaluation study by the U. S. Air Force Space and Missile Systems Organization (SAMSO). It was necessary to determine the properties of the specific materials for evaluation of the area as a hard rock medium and, as necessary, for design of structures in the medium. Results of tests on cores from Natrona and Fremont Counties in Wyoming, designated the Warren II area, are reported herein.

1.2 OBJECTIVE

The objective of this investigation was to conduct laboratory tests on samples from areas containing hard, near-surface rock to determine the integrity and the mechanical behavior of the materials as completely as possible, analyze the data thus obtained, and report the results to appropriate users.

1.3 SCOPE

Laboratory tests were conducted as indicated in the following paragraph on samples received from the field. Table 1.1 gives pertinent information on the various tests.

Tests conducted to determine the general quality, uniformity, and integrity of the rock in the area sampled were: (1) relative hardness (Schmidt number), (2) specific gravity, (3) unconfined compression (conventional and cyclic compression), and (4) dynamic elastic properties. Special tests conducted, respectively, to determine the degree of anisotropy of the sampled rock and to facilitate comparison of results of direct and indirect tensile tests were: (1) dynamic elastic properties along three mutually perpendicular axes and (2) tensile strength. A limited petrographic examination was also made.

1.4 SAMPLES

Samples were received from five holes in the Warren II area. These holes were designated W2-CR-1, -4, -5, -14, and -26. All samples were NX size cores (nominal 2-1/8-inch[1] diameter). Test specimens of the required dimensions as presented in Table 1.1 were prepared for the individual tests. Quality and uniformity tests were conducted on selected specimens from all holes. Special tests were conducted on specimens selected from the various core holes to represent differences in rock type, weathering, etc.

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[1] A table of factors for converting British units of measurement to metric units is presented on page 7.

1.5 REPORT REQUIREMENTS

The immediate need for the test results required that data reports be compiled and forwarded to the users as work was completed on each hole. The data reports of the individual test results are included herein as Appendixes A through E.

The core descriptions originally given in the data reports (Appendixes A through E) were frequently taken from the core logs received with the sample shipments. These descriptions have been changed, where necessary, to reflect the results of the petrographic examination and analysis performed at a later date.

TABLE 1.1 SUMMARY OF TESTS

Test	Specimen Size	Test Equipment	Recording Equipment	Measured Properties	Computed Properties
Relative hardness	1 diameter by 2 diameters	Schmidt hammer	--	Relative hardness	--
Specific gravity		Scales	--	Specific gravity	Density
Indirect tension		440,000-pound test machine	--	Tensile strength	--
Direct tension		30,000-pound test machine	--	Tensile strength	--
Unconfined compression		440,000-pound test machine	X-Y recorder	Compressive strength	--
Cyclic compression		440,000-pound test machine	X-Y recorder	Compressive strength	Young's, shear, and bulk moduli and Poisson's ratio
Ultrasonic velocity		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio
Dynamic elastic moduli		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	--
Petrographic examination	Variable	Microscopes, X-ray diffraction	--	Appearance, texture, and mineralogy	--
Anisotropy	1 diameter by 1 diameter	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio

CHAPTER 2

TEST METHODS

2.1 SCHMIDT NUMBER

The Schmidt number is a measure of the relative degree of hardness as determined by the degree of rebound of a small mass propelled against a test surface. The test was conducted as suggested in Reference 1 (a Swiss-made hammer was used) except that 8 to 12 readings per specimen were made. The average of these readings is the Schmidt number or relative hardness. The hardness is often taken as an approximation of rock quality, and may be correlated with other physical characteristics such as strength, density, and modulus.

2.2 SPECIFIC GRAVITY

The specific gravity of the "as-received" samples was determined by the loss of weight method conducted according to Method CRD-C 107 (Reference 2). A pycnometer is utilized to determine the loss of weight of the sample upon submergence. The specific gravity is equal to the weight in air divided by the loss of weight in water.

2.3 INDIRECT TENSION

The tensile strength was determined by the indirect method, commonly referred to as the tensile splitting or Brazilian method, in which a tensile failure stress is induced in a cylindrical test

specimen by a compressive force applied on two diametrically opposite line elements of the cylindrical surface. The test was conducted according to Method CRD-C 77 (Reference 2).

2.4 DIRECT TENSION

For purposes of comparison, specimens were prepared and tested for tensile strength according to the American Society for Testing and Materials (ASTM) proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." Tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens.

For the direct tension tests, the specimens were right circular cylinders, the sides of which were straight to within 0.01 inch over the full length of the specimen and the ends of which were parallel and not departing from perpendicularity to the axis of the specimen by more than 0.25 degree. Cylindrical metal caps were cemented to the ends of the specimen and provided the means for applying the direct tensile load. The load was applied continuously by a 30,000-pound-capacity universal testing machine and at a constant rate such that failure occurred within 5 to 15 minutes.

2.5 COMPRESSIVE STRENGTH TESTS

The unconfined and cyclic compression test specimens were prepared according to ASTM and Corps of Engineers standard method of

test for triaxial strength of undrained rock core specimens, CRD-C 147 (Reference 2). Essentially, the specimens were cut with a diamond blade saw, and the cut surfaces were ground to a tolerance of 0.001 inch across any diameter with a surface grinder prior to testing. Electrical resistance strain gages were utilized for strain measurements, two each in the axial (vertical) and horizontal (diametral) directions. Static Young's, bulk, shear, and constrained moduli were computed from strain measurements. Stress was applied with a 440,000-pound-capacity universal testing machine.

2.6 DYNAMIC PROPERTIES

Compressional and shear wave velocities, bulk, shear, and Young's moduli, and Poisson's ratio were determined by the ASTM proposed "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock." The method consisted essentially of generating a wave in the specimen with a pulse generator unit and measuring, with an oscilloscope, the time required for the compression and shear waves to travel the length of the specimen, the resulting wave velocity being the distance traveled divided by the travel time. These compressive and shear velocities, along with the bulk density of the specimen, were used to compute the elastic properties.

In the case of the special tests used to determine the degree of

anisotropy of the samples, compression and shear velocities were measured along two mutually perpendicular, diametrical (lateral) axes and along the longitudinal axis. This was facilitated by grinding four 1/2-inch-wide strips down the sides of the cylindrical surface at 90-degree angles and generating the compressive and shear waves perpendicular to these ground surfaces.

2.7 PETROGRAPHIC EXAMINATION

A limited petrographic examination was conducted on samples selected to be representative of the material from the several holes. The examination was limited to identifying the rock, determining general condition, identifying mineralogical constituents, and noting any unusual characteristics which may have influenced the test results.

CHAPTER 3

QUALITY AND UNIFORMITY TESTS

3.1 TESTS UTILIZED

Based on past experience with tests on samples received from areas previously evaluated,[1] the following tests were selected for use in determining the quality and uniformity of the Warren II area rock: compressional wave velocity, unconfined compressive strength, Schmidt number, and specific gravity.

Core samples from the five holes in the Warren II area were petrographically identified as predominantly biotite gneiss and granite. Several specimens of the core were identified as amphibolite gneiss and biotite schist. A few of the granite specimens were weathered. Scattered specimens from many of the holes contained: (1) contact zones between the granites and the other type materials and (2) macrofractures, some open, some closed.

Due to the many variables which influenced the testing, it was considered expedient to group the test results according to compressive strength as given below:

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[1] A list of associated reports is given on the inside front cover of this report.

Group	Rock Quality	Compressive Strength
		psi
1	Poor	<8,000
2	Marginal	8,000 to 12,000
3	Good to excellent	12,000 and above

3.2 POOR QUALITY ROCK

The incompetent rock (compressive strength less than 8,000 psi) was predominantly schist and gneiss as given below. The description denotes the field-given names unless the petrographic work dictated a different nomenclature.

Hole No.	Specimen No.	Description	Specific Gravity	Schmidt No.	Compressive Strength	Compressional Wave Velocity
					psi	fps
W2-CR-4	4	Biotite schist[a]	2.906	--	3,500	8,995
	5	Biotite schist[a]	2.858	--	2,800	11,625
	13	Amphibolite gneiss[a]	2.916	14.0	1,210	7,225
	15	Amphibolite gneiss[a]	3.070	21.8	5,990	11,675
	21	Granite gneiss	2.986	43.2	6,240	16,655
		Average	2.947	26.3	3,950	11,235

[a] Petrographic description.

Due to the presence of different types of rock, the specific gravity results for this area would not necessarily be a good indicator of rock quality. For example, the specific gravity results in the above tabulation are very high for rock, but the other physical tests indicate rather incompetent material.

Poor quality rock comprised 10 percent of the material tested. It should be noted also that the amount of poor quality rock is probably exaggerated with respect to the number of samples received for testing since preference was given in selecting test samples to specimens which contained defects or disparities.

3.3 MARGINAL MATERIAL

A second small group of test specimens yielded compressive results which may be termed marginal (compressive strength 8,000 to 12,000 psi).

Hole No.	Specimen No.	Description	Specific Gravity	Schmidt No.	Compressive Strength	Compressional Wave Velocity
					psi	fps
W2-CR-4	1	Granite gneiss	2.633	55.8	8,400	17,140
	16	Granite gneiss	2.589	--	10,650	16,185

(Continued)

Hole No.	Specimen No.	Description	Specific Gravity	Schmidt No.	Compressive Strength	Compressional Wave Velocity
					psi	fps
W2-CR-4	17	Amphibolite gneiss[a]	3.095	--	9,170	16,055
W2-CR-5	2	Biotite gneiss	2.655	32.1	--[b]	--[b]
	7	Biotite gneiss	2.670	57.8	11,510	19,300
	11	Biotite gneiss	2.704	46.8	10,940	17,205
W2-CR-14	1	Weathered granite	2.620	40.3	11,340	8,590
		Average	2.709	46.6	10,335	15,745

[a] Petrographic description.
[b] Specimen broke during preparation.

Although the strength results indicate the rock quality to be marginal, the Schmidt number and the compressional wave velocity results are not definitive. However, it should be noted that the nature of fractures detrimentally affecting the strength, primarily banding, would not necessarily affect the relative hardness or velocity if the bands were very tight, as apparently they were.

3.4 GOOD TO EXCELLENT QUALITY ROCK

Most of the rock described as intact gneiss or granite was good to excellent quality material, depending on the strengths obtained. Results are given as follows.

Hole No.	Speci-men No.	Description	Spe-cific Grav-ity	Schmidt No.	Compres-sive Strength	Compres-sional Wave Velocity
					psi	fps
W2-CR-1	2	Diorite, critically fractured[a]	2.764	--	12,420	15,730
	3	Granite porphyry[a]	2.736	--	21,210	20,400
	4	Granite porphyry	2.652	61.8	22,580	20,705
	5	Granite porphyry, incipient fracture[a]	2.729	61.1	18,180	20,610
	8	Granite porphyry, incipient fracture	2.655	63.2	31,060	20,760
	9	Granite porphyry	2.767	61.4	25,000	20,730
	10	Granite porphyry, incipient fracture	2.639	60.8	35,760	20,850
	11	Pink granite, fine grained	2.635	--	48,180	20,435
	12	Granite porphyry	2.649	--	28,030	20,240
	15	Granite porphyry[a]	2.739	59.2	24,240	20,610
	20	Granite porphyry, fractured	2.671	60.7	13,640	20,055
	23	Granite porphyry[a]	2.681	64.2	21,670	20,155
W2-CR-4	10	Amphibolite gneiss	3.024	58.8	25,860	22,715
	12	Amphibolite gneiss[a]	3.014	--	19,520	21,865
	18	Granite	2.684	--	15,950	18,195
	22	Granite	2.670	60.4	25,380	19,795
W2-CR-5	9	Biotite gneiss	2.677	60.8	20,480	18,505
	14	Biotite gneiss	2.726	45.6	22,090	18,095
	18	Biotite gneiss	2.691	--	22,120	19,820
	19	Biotite gneiss, vertically fractured	2.691	57.2	18,180	19,945
	20	Biotite gneiss, vertically fractured	2.728	--	12,550	19,430
	21	Biotite gneiss	2.732	58.4	21,340	20,235
	22	Biotite gneiss	2.703	56.3	16,300	20,085
W2-CR-14	5	Slightly weathered granite	2.640	56.6	22,790	18,655
	7	Slightly weathered granite	2.640	--	20,910	18,630
	8	Slightly weathered granite	2.644	56.2	22,510	18,575
	10	Slightly weathered granite	2.644	56.0	21,400	18,425
	14	Slightly weathered granite	2.639	--	17,300	18,875
	16	Unweathered granite	2.645	61.3	24,360	18,935
	19	Unweathered granite	2.646	60.1	21,880	18,110
	21	Unweathered granite	2.641	61.5	23,880	19,140
W2-CR-26	2	Vertically fractured granite	2.645	--	28,700	18,225
	3	Vertically fractured granite	2.668	--	27,270	17,280
	5	Intact granite	2.648	52.8	29,700	19,415
	6	Intact granite	2.648	49.8	28,790	18,760
	9	Intact granite	2.636	48.7	25,230	18,140
	10	Intact granite	2.630	48.6	31,670	18,660
	14	Intact granite	2.639	49.9	30,080	18,560
	18	Intact granite	2.636	49.8	30,160	18,000
		Average	2.691	57.1	23,800	19,395

[a] Petrographic description.

Only six of the specimens yielded compressive strengths of less than 18,000 psi, the lower limit of what may be considered excellent quality rock. The remainder of the specimens, representing 66 percent of the specimens tested from this area, gave strengths approximating 25,000 psi--an acceptable level of confidence for the better rock. Compressional wave velocities were sufficiently high to indicate few, if any, flaws in the good to excellent quality material.

CHAPTER 4

SPECIAL TESTS

4.1 COMPARATIVE TENSILE TESTS

Five NX-diameter rock specimens were selected to represent the variation of rock type and weathering present in the core. The specimens were prepared and tested for tensile strength according to the ASTM proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." For comparative purposes, tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens. Results are given in Table 4.1. Generally, the direct tensile strength averaged approximately 80 percent of the tensile splitting strength. The gneiss and the brown (possibly weathered) granite yielded strengths significantly lower than the better granite.

4.2 ELASTIC MODULI

Samples representative of the different materials in each hole were selected for deformation moduli tests for the data reports. After dynamic tests were completed, a portion of each sample was prepared for static testing. Static moduli were computed from measurements taken from electrical resistance strain gages affixed to the specimens. Results are given in Table 4.2.

The poor and marginal quality rock yielded very erratic moduli

determinations. This is not unexpected in an anisotropic rock since the strain gages would not necessarily average the strains over a fractured or composite material. The moduli of the more competent core were indicative of relatively brittle, rigid rock.

Examination of the stress-strain curves in the data reports reveals that the intact granite is predominantly linear-elastic to approximately half of the ultimate strength. However, significant hysteresis and residual strain are evident in most of the gneiss specimens even under small stresses. Some erratic behavior occurred on several specimens in which the strain gages had apparently been placed over fractures or contact zones. The fact that slippage occurred prior to ultimate failure is evidence that many of the fractures and contacts were very tight.

4.3 ANISOTROPY TESTS

To determine the degree of anisotropy, five rock specimens were selected and prepared for determination of compression (dilatational) and shear velocities in three directions according to the ASTM proposed "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock." The NX-diameter specimens were cut to lengths of approximately 2 inches and ground on the ends to a tolerance of 0.001 inch. Four 1/2-inch-wide strips were also ground down the sides of the cylindrical surface at

90-degree angles. Compressive and shear velocities were determined in three directions, on one vertical and two mutually perpendicular lateral axes. The velocities, densities, and dimensions were measured as specified in the proposed test method. Results of the velocity determinations are given in Table 4.3.

All of the material yielded compressive and shear velocities indicative of competent rock. The shear velocities consistently averaged approximately 60 percent of the compressive velocities. Specimen W2-CR-5-16, described as quartz biotite gneiss, yielded velocities which would indicate a high degree of anisotropy in the gneissic material from this area.

A compilation of the elastic properties computed from the compressive and shear velocities and the specific gravity is given in Table 4.4. However, discretion must be used in utilizing the moduli results since experimental errors are introduced when the differences in velocities are significant. The proposed ASTM test method states that the equations for computation of elastic moduli should not be used if "any of the three compressional wave velocities varies by more than 2 percent from their average value. The error in E and G due to both anisotropy and experimental error then does not exceed 6 percent." Naturally, the effect of the error is compounded by greater differences in the three-directional velocity measurements.

4.4 PETROGRAPHIC EXAMINATION

4.4.1 Samples. Five boxes of NX core from holes in Fremont and Natrona Counties, Wyoming, were received in August 1969 for testing. Each box contained about 15 feet of core which represented several depths to 200 feet.

The cores were inspected to select representative pieces from all significant rock types for petrographic examination. The cores are described below:

Hole W2-CR-1. The core was brownish-gray and white, coarse-grained rock, logged as granite porphyry; gray and white medium-grained rock, logged as diorite; and pink, fine-grained rock, logged as fine-grained granite. The entire core appeared to be unweathered and very massive. A few high-angle fractures were present.

Sections 1, 3 through 10, 12 through 17, and 20 through 26 were light brownish-gray, coarse-grained porphyritic rock. This rock contained medium-grained phases that appeared to be assimilated diorite.

Sections 11, 18, and 19 were pink, fine-grained rock which was logged as granite.

Section 2 was diorite, which may have been assimilated by the granite.

Hole W2-CR-4. There were three rock types in this hole: a biotite schist, an amphibole gneiss, and a coarse-grained rock logged

as granite. Sections 1 through 6 were weathered and the rest of the sections were fresh.

Sections 2 through 6 were weathered, medium-grained biotite schist. The biotite was slightly altered to chlorite. This rock contained several randomly oriented fractures.

Sections 1, 9, 16, 18, 21, and 22 were pink and white, coarse-grained, massive rock.

Sections 7, 8, 10 through 15, 17, 19, and 20 were black and white, medium-grained amphibolite gneiss. There were a few fractures and joints present.

Hole W2-CR-5. The entire core was fine- to coarse-grained biotite gneiss and schist.

Sections 1 through 13 were fine-grained biotite gneiss and the remainder of the core was coarse-grained biotite schist and gneiss.

Section 15 contained a granitic inclusion. Most of the sections contained minor sealed fractures.

Hole W2-CR-14. The entire core was brownish-gray, coarse-grained rock, logged as granite.

Sections 1 through 8 were weathered. Fractures were not common in these sections or in the remainder of the core.

Hole W2-CR-26. The entire core was brownish-gray, coarse-grained rock, logged as granite. All sections were fresh and only Sections 2 and 3 contained fractures.

4.4.2 Specimens Selected. The specimens selected for petrographic examination were:

Hole No.	CD Serial No.	Specimen No.	Approximate Depth	Rock Description (Colors According to Reference 3)
			feet	
W2-CR-1	SAMSO-8, DC-1	11	90	Pale red (10R 6/2) aplite
		21	168	Light brownish-gray (5YR 6/1) and white (N9) to light brownish-gray (5YR 6/1) and black (N1) tonalite
		26	200	Light brownish-gray (5YR 6/1) and white (N9) granite
W2-CR-4	SAMSO-8, DC-3	6	68	Greenish-black (5G 2/1) hornblende-biotite schist
		8	103	Greenish-black (5GY 2/1) hornblende-plagioclase gneiss
		9	109	Grayish-pink (SR 8/2) tonalite pegmatite
		20	182	Black (N1) amphibolite gneiss
W2-CR-5	SAMSO-8, DC-4	6	57	Medium gray (N5) biotite gneiss
		15	130	Greenish-black (5GY 2/1) biotite schist

(Continued)

Hole No.	CD Serial No.	Specimen No.	Approximate Depth	Rock Description (Colors According to Reference 3)
			feet	
W2-CR-14	SAMSO-8, DC-5	12	123	Light gray (N7) and dark yellowish-orange (10YR 6/6) granite
W2-CR-26	SAMSO-8, DC-2	17	173	Medium light gray (N6) and white (N9) granite

4.4.3 Test Procedure. Each piece of core was sawed axially. One sawed surface of each piece was polished and photographed. Composite samples were obtained from the whole length or from selected portions from the remaining half of each piece. The composite samples were ground to pass a No. 325 sieve (44μ). X-ray diffraction (XRD) patterns were made of each sample as a tightly packed powder. All XRD patterns were made using an XRD-5 diffractometer with nickel-filtered copper radiation. The samples X-rayed are listed as follows:

Hole No.	Specimen No.	Description of X-Ray Sample
W2-CR-1	11	Entire length of core was sampled
	21a	Coarse-grained half was sampled
	21b	Medium-grained half was sampled
	26	Entire length was sampled

(Continued)

Hole No.	Specimen No.	Description of X-Ray Sample
W2-CR-4	6	Entire length was sampled
	8	Entire length was sampled
	9	Entire length was sampled
	20	Entire length was sampled
W2-CR-5	6	Entire length was sampled
	15	Entire length except for granitic inclusion was sampled
W2-CR-14	12	Entire length was sampled
W2-CR-26	17	Entire length was sampled

Small portions of the powdered samples were tested with dilute hydrochloric acid and with a magnet to determine whether carbonate minerals or magnetite were present.

The polished surface of each section was examined with a stereomicroscope. Thin sections were prepared from each section of core and examined with a polarizing microscope. A point-count modal analysis was made on each thin section, in which 500 points were counted.

4.4.4 Results. The cores examined from the Warren II area can be divided into five groups: porphyritic granites (Reference 4), tonalites (Reference 4), aplite granites (Reference 4), biotite gneisses and schists, and amphibolite schists and gneisses. The

cores were taken from pre-Cambrian rocks in the Sweet Water or Granite Mountains uplift (Reference 5) of central Wyoming, and are very similar to the Sherman Granite Facies (Reference 6) of the southern Laramie Range. The rock types are discussed below. The modal composition of each type is shown in Table 4.5 and the bulk composition by X-ray diffraction in Table 4.6.

Granites. Cores W2-CR-14 and -26 and parts of Core W2-CR-1 were granites which contained phenocrysts of microcline, perthite, and microperthite in a coarse-grained matrix of equigranular quartz, plagioclase, and biotite (Figures 4.1 and 4.2). The phenocrysts had a maximum diameter of 1.5 inches and were euhedral to subhedral. The microcline was unaltered, while plagioclase was usually severely altered to sericite. Biotite was slightly altered to chlorite. Primary flow structures were not detected in any of the sections. Microfractures were common in the granites and were prominent in the phenocrysts of potash feldspar. Alteration of the minerals was greatest along these fractures.

Section 26 of Core W2-CR-1 was typical of the granite in this core. The plagioclase, containing 18 percent anorthite, was moderately altered to sericite; the microcline was not altered. The quartz had been strained and fractured, and hematitic stain had been introduced along the fractures, giving the quartz and the rock an unusual brown color.

Section 12 of Core W2-CR-14 contained more microcline than the other two granite sections, but the texture and degree of alteration are similar to Section 26 of W2-CR-1. The majority of the plagioclase was oligoclase, except for the plagioclase in the perthite, which was very fresh andesine containing 33 percent anorthite.

Section 17 of Core W2-CR-26 was similar to Section 26 of W2-CR-1, except that it was more altered. Plagioclase and biotite were often broken and severely altered. Microcline did not show the effects of the alteration.

Tonalites. Tonalites (parts of Cores W2-CR-1 and -4) were less abundant than granites and were not porphyritic (Figure 4.3). The tonalites were identified on the field logs as granites. They were classified in this investigation as tonalites (Reference 4) because they contained more plagioclase than the granites and more plagioclase than microcline. Plagioclase comprised about 40 percent of the rock, with microcline and quartz comprising about 28 percent each. Biotite was the dominant ferromagnesian mineral in the rocks.

Section 21 of Core W2-CR-1 was medium- to coarse-grained biotite tonalite (Figure 4.3). The medium-grained part of the section contained more biotite than the coarse-grained part and was darker in color. The medium-grained part (21b) had a weak planar structure that dipped at about 45 degrees from the vertical (Figure 4.3). This structure was not apparent in the coarse-grained part (21a). Aside

from the slight difference in amount of biotite (Table 4.5), the two parts of the section had similar compositions.

The microcline was very fresh and was perthitic. The quartz had been severely strained and fractured. The plagioclase was severely altered to sericite. The degree of alteration increased in the medium-grained part of the section.

Section 9 of Hole W2-CR-4 was typical of the tonalite in this hole and was markedly different from the tonalite in Hole W2-CR-1 (Figure 4.3). It was very coarse-grained and contained a trace of biotite and bands of garnet. The plagioclase contained 33 percent anorthite and was more calcic than the plagioclase in the other tonalites. The rock may be a dike rock.

Aplite Granites. Parts of Core W2-CR-1 were accurately identified on the field log as fine-grained granite. Their equigranular texture and the absence of dark minerals cause them to be classified as aplite granites in the Shand system (Reference 4). Section 11 of Core W2-CR-1 was representative of this rock type. Its composition was similar to that of Section 12 of Core W2-CR-14 (granite), but it was fine-grained (Figure 4.4), and had a cataclastic texture. This rock may have been originally similar to that granite but was later granulated. The minerals are altered and the grain boundaries are sutured.

Amphibolites. Parts of Core W2-CR-4 were rocks which ranged

from hornblende-mica to hornblende-plagioclase rocks (Figures 4.5 and 4.6). Euhedral to subhedral hornblende, near to edenite, was the predominant mineral in these rocks. All were medium-grained, foliated, and fairly dark colored. The hornblende showed only slight alteration to chlorite.

Section 6 of Core W2-CR-4 was very porous and severely weathered. It contained a large amount of highly altered biotite and no plagioclase or quartz. The biotite was altered to chlorite but the hornblende was very fresh. There were many fractures at random angles (Figure 4.5).

Section 8 of Core W2-CR-4 was similar to Core W2-CR-4, Section 20 (described i next paragraph), but contained less quartz and a less calcic andesine plagioclase (An_{36}). The hornblende was very fresh and the plagioclase was severely altered to sericite. High-angle and horizontal fractures were present. A pegmatite dike followed an earlier high-angle fracture.

Section 20 of Core W2-CR-4 contained a calcic plagioclase (andesine containing 47 percent anorthite) that was severely altered to sericite. Quartz was present as interstitial grains that exhibited straight extinction. There were several horizontal fractures that paralleled the schistosity. A quartz vein cut the rock at an angle of about 40 degrees from the vertical (Figure 4.6).

<u>Biotite Gneisses and Schists</u>. The majority of the sections of

Core W2-CR-5 were fine- to coarse-grained biotite, plagioclase gneiss (Figure 4.7). A few scattered sections of biotite schist were present in the core. The gneisses were very fresh while the schists were severely altered.

Section 6 of Hole W2-CR-5 was typical of the gneiss. It had a well-developed nearly horizontal foliation that was paralleled by numerous sealed fractures (Figure 4.7). The plagioclase was fresh oligoclase (An_8). Quartz appeared unstrained, not fractured, and exhibited straight extinction. Biotite was very fresh.

Section 15 of Hole W2-CR-5 was a coarse-grained biotite, quartz schist in which the biotite altered to chlorite (Figure 4.7). Quartz formed composite grains, with straight extinction and non-sutured borders, which suggested recrystallization of the quartz.

4.4.5 Summary. Petrographic examination of eleven sections of core from five holes in the Sweetwater Mountains area of central Wyoming revealed that five rock types were represented: granite porphyry, tonalite, aplite granite, amphibolite, and biotite gneiss and schist. The granites and gneisses were the most abundant rock types in the cores. Differences in compressive strength and elastic properties among the rocks of each type seem to have arisen from the number and inclination of fractures, whether the fractures were open or sealed, and degree of alteration due to weathering. The mineral

compositions are summarized in Tables 4.5 and 4.6, and the sections examined are illustrated in Figures 4.1 through 4.7.

TABLE 4.1 TENSILE STRENGTH DETERMINATIONS

Hole No.	Specimen No.	Depth	Tensile Strength			Rock Type
			Splitting	Direct	Direct/ Splitting	
		feet	psi	psi	percent	
W2-CR-1	24	192	1,110	1,030	93	Porphyritic granite
W2-CR-5	16	137	555	300	54	Quartz biotite gneiss
W2-CR-14	3	44	665	610	92	Brown granite
W2-CR-14	17	170	990	720	72	Gray granite
W2-CR-26	13	133	1,180	1,090	92	Gray granite
				Average	80	

TABLE 4.2 ELASTIC MODULI RESULTS

Hole No.	Specimen No.	Description	Dynamic Modulus			Static Modulus		
			Young's	Bulk	Shear	Young's	Bulk	Shear
			10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi
Poor and Marginal Quality Rock:								
W2-CR-4	1	Granite gneiss	6.6	7.1	2.5	6.9	3.1	3.1
	5	Biotite schist	3.6	3.4	1.4	--	--	--
	15	Amphibolite gneiss	4.8	3.0	2.0	2.0	1.3	0.8
	17	Amphibolite gneiss	8.2	6.5	3.2	--	--	--
W2-CR-5	7	Biotite gneiss	10.0	7.6	4.4	8.1	3.6	3.6
	11	Biotite gneiss	8.5	6.4	3.3	6.6	3.7	2.7
		Average	7.0	5.7	2.6	5.9	2.9	2.6
Good and Excellent Quality Rock:								
W2-CR-1	2	Fractured diorite	8.0	4.9	3.5	--	--	--
	4	Granite porphyry	12.6	8.6	5.0	9.2	5.3	3.8
	5	Granite porphyry	11.3	9.8	4.4	9.1	5.1	3.8
	11	Pink granite	12.7	7.9	5.2	10.5	6.2	4.3
	20	Granite porphyry	11.9	8.2	4.7	--	--	--
W2-CR-4	12	Amphibolite gneiss	13.0	12.9	4.9	12.3	6.2	5.3
W2-CR-5	21	Biotite gneiss	12.7	8.2	5.1	10.4	6.2	4.3
W2-CR-14	5	Slightly weathered granite	8.7	8.0	3.3	7.8	4.8	3.2
	10	Slightly weathered granite	9.2	7.4	3.5	8.2	5.4	3.3
	19	Unweathered granite	10.0	6.3	4.1	8.9	7.4	3.4
W2-CR-26	3	Fractured granite	9.1	5.9	3.6	7.8	4.4	3.2
	9	Intact granite	8.3	7.5	3.2	7.1	5.2	2.8
	18	Intact granite	8.9	6.9	3.4	8.3	5.6	3.3
		Average	10.5	7.9	4.1	9.0	5.6	3.7

TABLE 4.3 VELOCITY DETERMINATIONS

		Velocity[a]	
		Compressional	Shear
		fps	fps
Hole W2-CR-1, Specimen 24:			
Porphyritic granite		21,380	11,530
Depth: 192 feet		20,580	11,920
Specific gravity: 2.68		20,870	11,940
Compressive deviation:[b] 2.1 pct			
	Average	20,940	11,800
Hole W2-CR-5, Specimen 16:			
Quartz biotite gneiss		18,660	11,820
Depth: 137 feet		20,890	11,030
Specific gravity: 2.77		15,520	9,960
Compressive deviation: 15.5 pct			
	Average	18,360	10,940
Hole W2-CR-14, Specimen 3:			
Brown granite		20,130	11,240
Depth: 44 feet		19,320	11,090
Specific gravity: 2.68		18,850	10,760
Compressive deviation: 3.6 pct			
	Average	19,430	11,030
Hole W2-CR-14, Specimen 17:			
Gray granite		18,830	11,360
Depth: 170 feet		18,210	10,360
Specific gravity: 2.69		17,800	10,430
Compressive deviation: 3.0 pct			
	Average	18,280	10,720
Hole W2-CR-26, Specimen 13:			
Gray granite		18,680	11,070
Depth: 133 feet		19,120	10,370
Specific gravity: 2.68		17,850	10,490
Compressive deviation: 3.8 pct			
	Average	18,550	10,640

[a] First velocity listed is in axial (longitudinal) direction; other two are on mutually perpendicular, diametral (lateral) axes.
[b] Maximum percent deviation from the average of the compressional wave velocity.

TABLE 4.4 ELASTIC PROPERTIES

Hole No.	Specimen No.	Moduli			Poisson's Ratio
		Young's	Bulk	Shear	
		10^6 psi	10^6 psi	10^6 psi	
W2-CR-1	24	12.40	10.10	4.80	0.30
		12.80	8.44	5.13	0.25
		12.90	8.87	5.15	0.26
	Average	12.70	9.14	5.03	0.27
W2-CR-5	16	12.10	6.06	5.22	0.17
		11.80	10.20	4.55	0.15
		8.52	4.06	3.70	0.31
	Average	10.81	6.77	4.49	0.21
W2-CR-14	3	11.60	8.55	4.56	0.27
		11.10	7.56	4.44	0.25
		10.50	7.24	4.18	0.26
	Average	11.07	7.78	4.39	0.26
	17	11.30	6.60	4.68	0.21
		9.80	6.82	3.89	0.26
		9.76	6.22	3.94	0.24
	Average	10.29	6.55	4.17	0.24
W2-CR-26	13	10.80	6.69	4.42	0.23
		10.00	8.02	3.88	0.29
		9.82	6.21	3.97	0.24
	Average	10.21	6.97	4.09	0.25

TABLE 4.5 MODAL COMPOSITION OF ROCKS FROM WARREN II AREA

Modes are based on 500 point counts per thin section.

Constituent	Granite			Tonalite			Aplite	Amphibolite			Biotite	
	W2-CR-1 Section 26	W2-CR-14 Section 12	W2-CR-26 Section 17	W2-CR-1 Section 21a	W2-CR-1 Section 21b	W2-CR-4 Section 9	W2-CR-1 Section 11	W2-CR-4 Section 6	W2-CR-4 Section 8	W2-CR-4 Section 20	Gneiss W2-CR-5 Section 6	Schist W2-CR-5 Section 15
Quartz	30	24	30	28	28	25	29	None	Trace	6	28	38
Plagioclase	31	28	30	40	37	44	28	None	33	20	54	None
(Anorthite content of plagioclase)	(18)	(17)	(15)	(19)	(18)	(33)	(15)	(--)	(36)	(47)	(18)	(--)
Microcline	30	43	33	26	27	27	42	None	None	None	None	None
Biotite	5	4	5	5	7	Trace	Trace	34	None	None	16	41
Muscovite	None	None	None	None	None	Trace	None	None	None	None	None	None
Chlorite	1	1	1	Trace	Trace	Trace	Trace	1	3	6	1	20
Hornblende	1	None	None	None	None	None	None	64	63	65	None	None
Epidote	None	Trace	Trace	Trace	Trace	None	Trace	None	Trace	Trace	None	None
Sphene	None	None	None	None	None	None	None	None	None	1	None	None
Apatite	None	Trace	Trace	Trace	Trace	None	None	None	None	Trace	None	None
Zircon	Trace	Trace	Trace	Trace	Trace	None	None	None	None	Trace	Trace	None
Garnet	None	None	None	None	None	3	None	None	None	None	None	None
Magnetite	1	Trace	1	Trace	Trace	Trace	None	1	Trace	1	1	1
Hematite	Trace	None	None	Trace	Trace	None	None	None	None	None	None	None
Kaolinite	1	None	None	Trace	Trace	None	None	None	None	None	None	None

TABLE 4.6 BULK COMPOSITION OF ROCKS FROM WARREN II AREA

Based on X-ray diffraction results and compared to W2-CR-1, Section 26. ND = none detected.

Constituent	Granite			Tonalite			Aplite	Amphibolite			Biotite	
	W2-CR-1 Section 26	W2-CR-14 Section 12	W2-CR-26 Section 17	W2-CR-1 Section 21a	W2-CR-1 Section 21b	W2-CR-4 Section 9	W2-CR-1 Section 11	W2-CR-4 Section 6	W2-CR-4 Section 8	W2-CR-4 Section 20	Gneiss W2-CR-5 Section 6	Schist W2-CR-5 Section 15
Quartz	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Abundant	Much less	ND	Much less	Abundant	Much more
Plagioclase	Abundant	Abundant	Abundant	Slightly more	Slightly more	Much more	Slightly less	ND	Abundant	Much less	Much more	ND
Microcline	Abundant	Slightly more	Abundant	Abundant	Abundant	Abundant	Slightly more	ND	ND	ND	ND	ND
(Plagioclase/microcline)	(1/1)	(2/3)	(1/1)	(3/2)	(3/2)	(3/2)	(2/3)	(--)	(--)	(--)	(--)	(--)
Biotite	Common	Common	Common	Common	Common	Much less	Much less	Abundant	ND	ND	Much more	Abundant
Chlorite	Minor	Much more	ND	ND	ND	ND	ND	ND	Minor	Slightly more	ND	Abundant
Hornblende	ND	ND	Minor	ND	ND	Minor	ND	Abundant	Abundant	Abundant	ND	ND
Magnetite	Minor	Minor	Minor	Minor	Minor	Minor	ND	Minor	Minor	Minor	Minor	Minor
Hematite	Minor	ND	ND	Slightly more	Slightly more	ND	ND	ND	ND	ND	ND	ND
Kaolinite	Minor	ND	ND	Minor	Minor	ND	ND	ND	ND	ND	ND	ND

Figure 4.1 Granite specimen, Core W2-CR-1, Section 26, showing typical porphyritic texture of the granites from the Warren II area. White specks near the black biotite are kaolinite. The large fractured grains are phenocrysts of microcline.

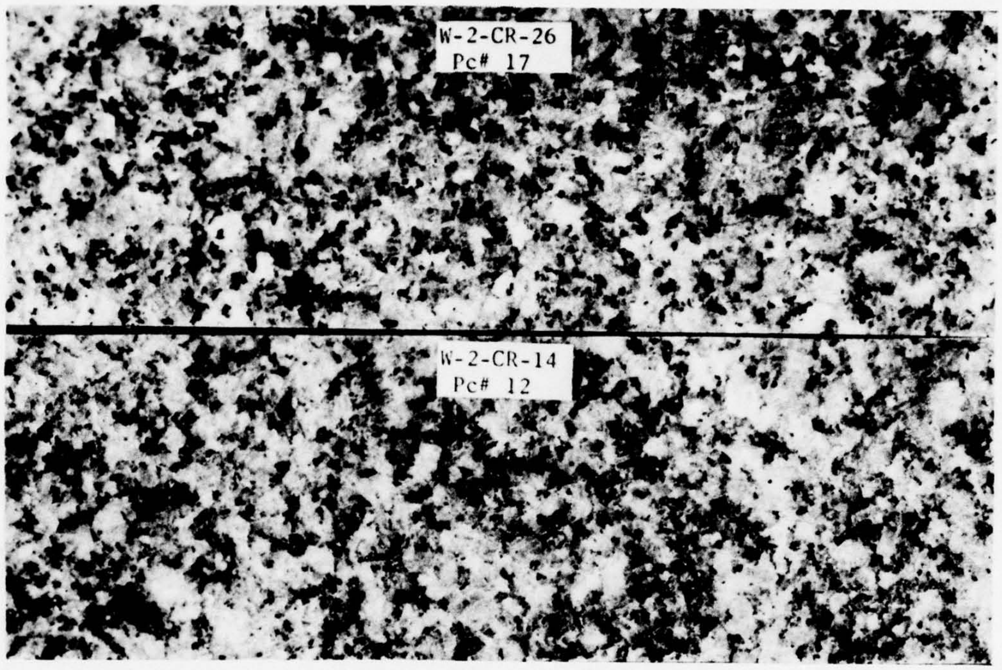


Figure 4.2 Granite specimens, Cores W2-CR-26, Section 17, and W2-CR-14, Section 12. W2-CR-26, Section 17, shows lack of porphyritic texture. Minute white lines are fractures. W2-CR-14, Section 12, is sheared and altered granite. Gray areas are hematite-stained quartz. White specks are kaolinite.

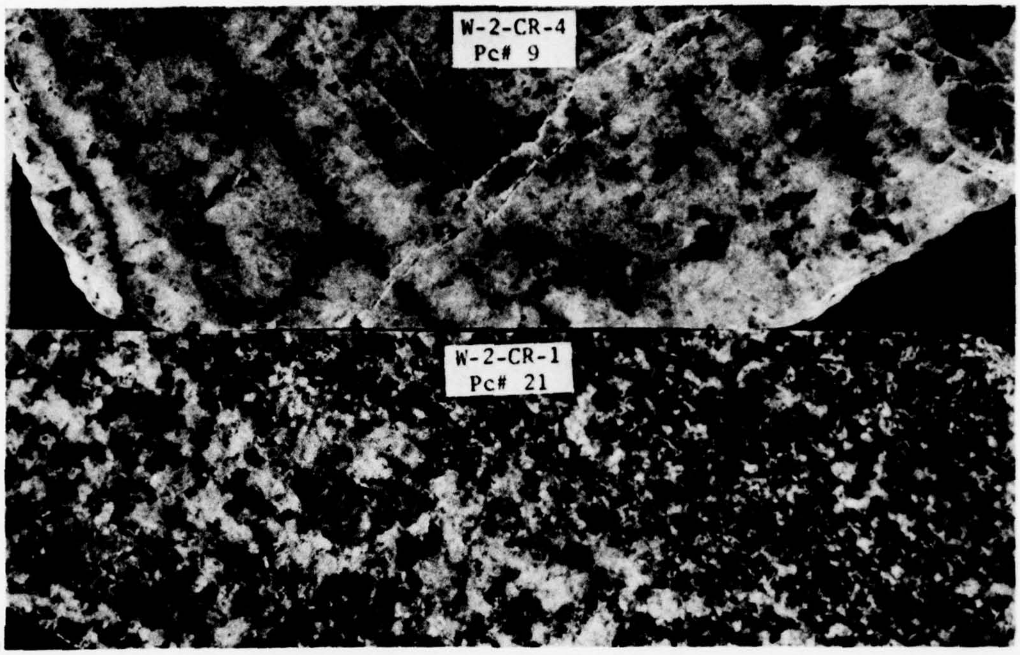


Figure 4.3 Tonalite specimens, Cores W2-CR-4, Section 9, and W2-CR-1, Section 21. W2-CR-4, Section 9, is coarse-grained tonalite. Dark band to the left of center is a garnet band along a sealed fracture. White lines are partially sealed fractures. The left portion of W2-CR-1, Section 21 (designated 21a in Tables 4.5 and 4.6), is coarse-grained porphyritic tonalite with phenocrysts of microcline. The right portion (21b) is medium-grained, biotite-rich tonalite, with biotite defining a strong foliation. Small white rhombs are kaolinite.

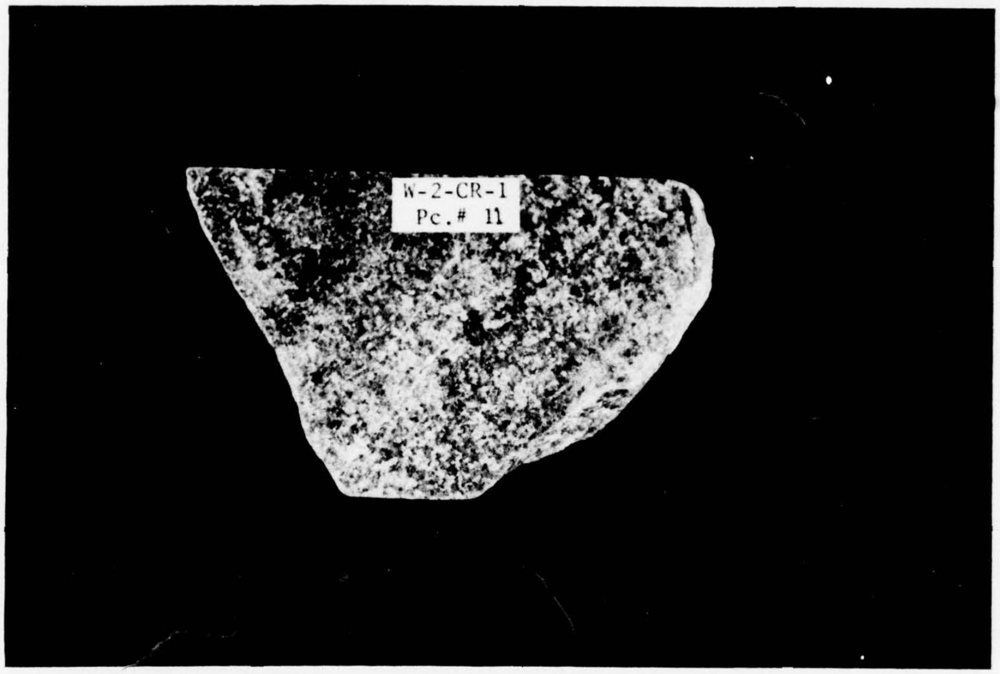


Figure 4.4 Aplitic granite specimen, Core W2-CR-1, Section 11, showing fine-grained texture. Narrow white lines are sealed fractures.

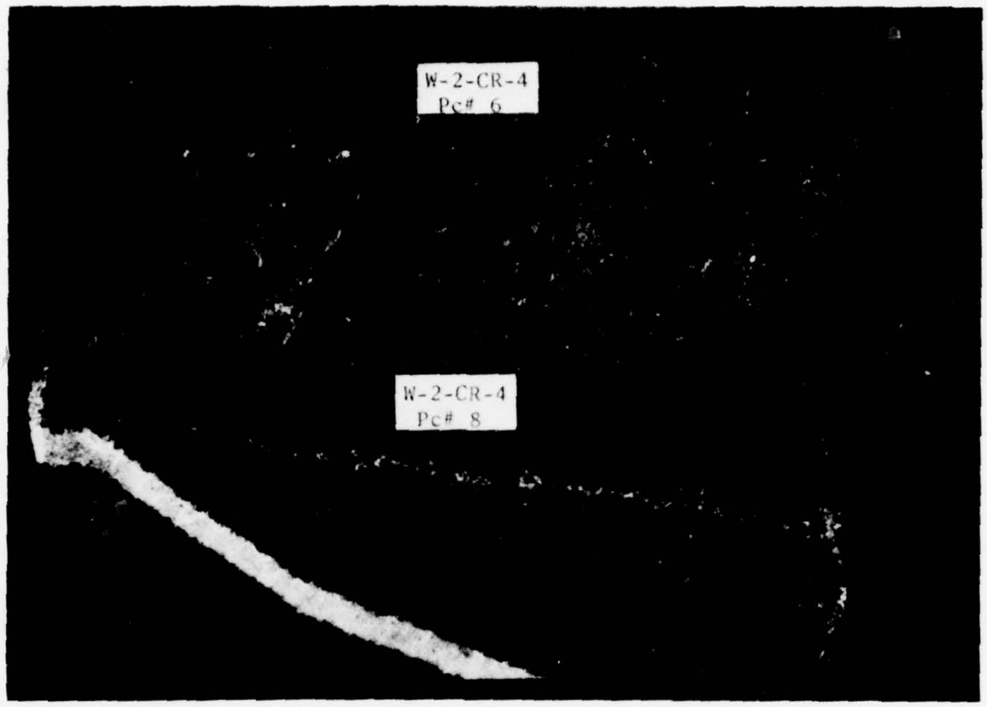


Figure 4.5 Amphibolite specimens, Core W2-CR-4, Sections 6 and 8. Section 6 is weathered hornblende-biotite schist with well-developed schistose structure. Section 8 is hornblende-plagioclase gneiss. Schistosity is in the same plane as that in Section 6. Fractures are at right angles and also serve as zone of weakness along which the quartz dike intruded.

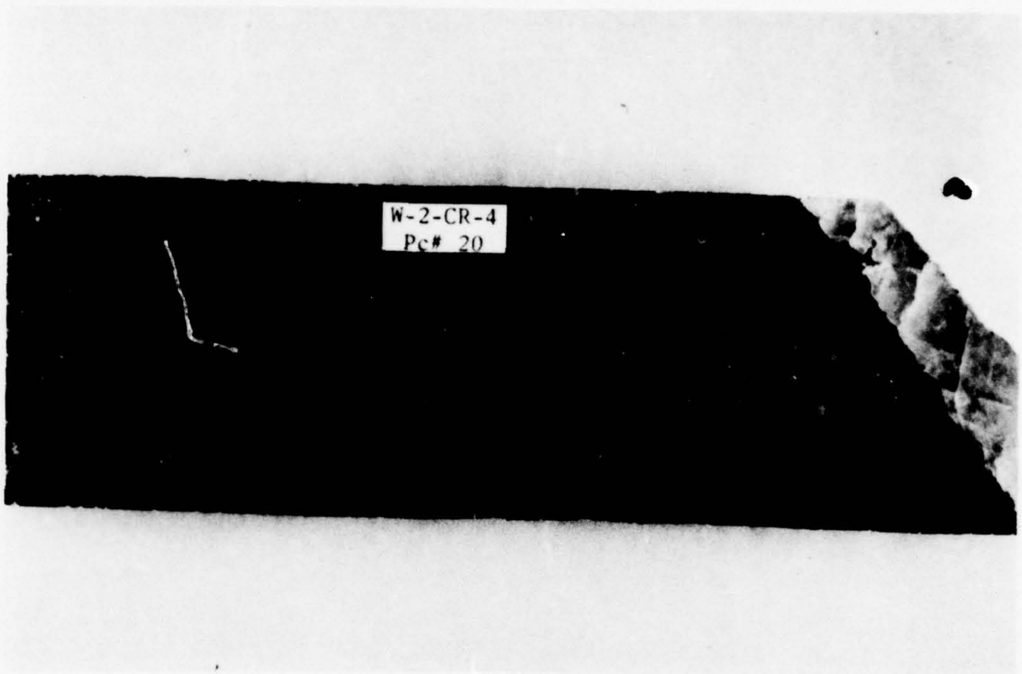


Figure 4.6 Amphibolite specimen, Core W2-CR-4, Section 20, showing horizontal foliation and nearly parallel fractures. Quartz dike (right) cuts the foliation.

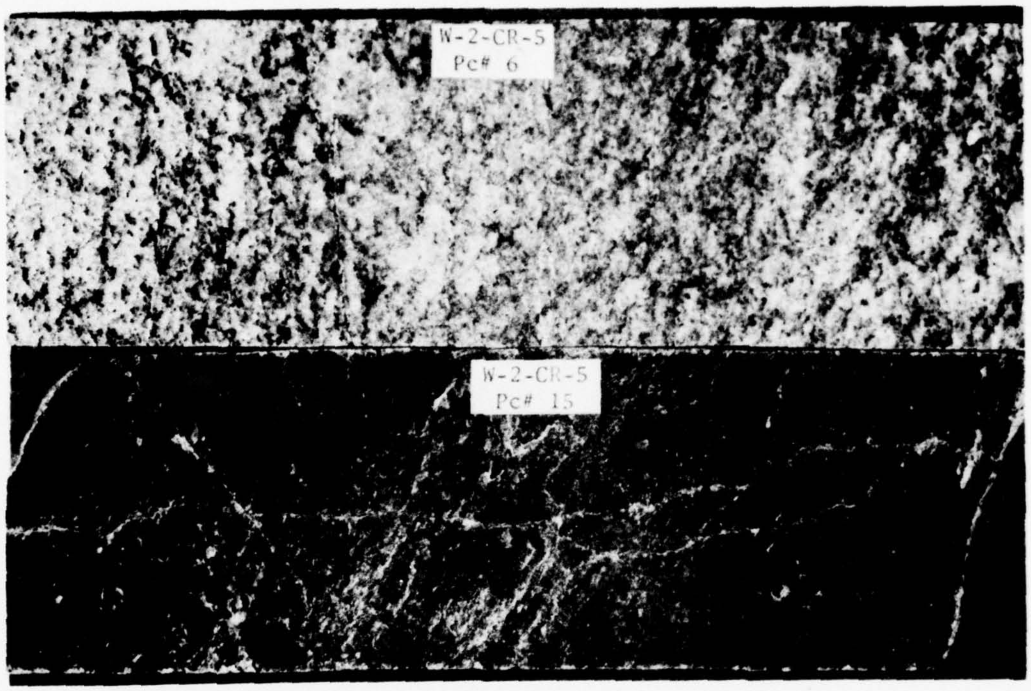


Figure 4.7 Biotite gneiss and schist specimens, Core W2-CR-5, Sections 6 and 15. Section 6 is highly fractured, well-foliated gneiss. Small white lines are fractures. Section 15 is highly fractured schist. White lines are partially sealed fractures. This rock may be an inclusion in the gneiss.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

The wide area covered by the drill holes from which core was taken (delineated in Figure 5.1) and the complex nature of the rock preclude assessment of the area on a geographical basis. The area is approximately 1,200 mi^2. The core is predominantly pink to gray granitic igneous rock; however, variations in grain size, mineral constituents, and degree of fracturing and weathering of the granite and the presence of several other rock types prevent classification as a uniform material. A rock quality chart based on compressive strength divided into three categories (poor, marginal, and good to excellent) was prepared (Figure 5.2). Except in Hole W2-CR-4, which contained very incompetent gneiss and schist scattered throughout, marginal quality rock occurs predominantly near the top of the holes, i.e., down to depths of 60 to 70 feet.

As mentioned previously, the physical properties are expectedly quite variable, in such a complex rock mass. The densest materials, the schists and some of the gneisses, were the least competent as indicated by the other tests. The strength results and compressional wave velocities, although quite variable, were satisfactory for the large majority of rock, including specimens which contained contacts

of the several rock types. Only 10 percent of the compressive specimens were classified as poor quality material and an additional 14 percent as marginal by the criteria utilized herein. Only 6 of 51 specimens had compressive wave velocities of less than 15,000 fps. Therefore, overall appearance of the area is one of a complex rock mass but within the complexity, a fairly competent medium.

5.2 CONCLUSIONS

Based on the test results of rock core samples reported herein, the following conclusions appear to be justified:

1. Petrographically, the samples give the appearance of representing a complex geologic area. Five general types of material were identified: porphyritic granite, tonalite, aplite granite, amphibolite, and biotite gneiss and schist. The predominant materials were granite and biotite gneiss.

2. Based on physical characteristics, three groups of material were present: poor, marginal, and good to excellent quality rock.

3. If 12,000-psi compressive strength is taken as the acceptable minimum of competence, 24 percent of all tested material would be classified as incompetent (compared to 17 percent in the Bergstrom area and 33 percent in the Castle area). Twelve percent of the specimens tested had compressive wave velocities below 15,000 fps.

4. The wide area represented by the five drill holes and the

complex nature of the material preclude assessment on a hole-to-hole basis. Except for the schist, poorer quality rock is predominantly in the upper elevation. One may expect to remove up to 70 feet of material in some areas before competent rock is reached.

5. Three-dimensional compressional wave velocity tests on representative samples indicate that the granite is rather isotropic; however, the one gneiss specimen varied 15 percent in velocity measurements, which would indicate the gneiss to be very anisotropic.

6. Except for the schist, the material from this area was rather brittle, exhibiting little or no plastic deformation prior to failure. Hysteresis and residual strain were evident in the elasto-plastic behavior of the schist.

7. Based on the limited data available, the area offers possibilities as a competent hard rock medium if the schist can be avoided. A more extensive investigation will be required to identify the most promising hard rock areas.

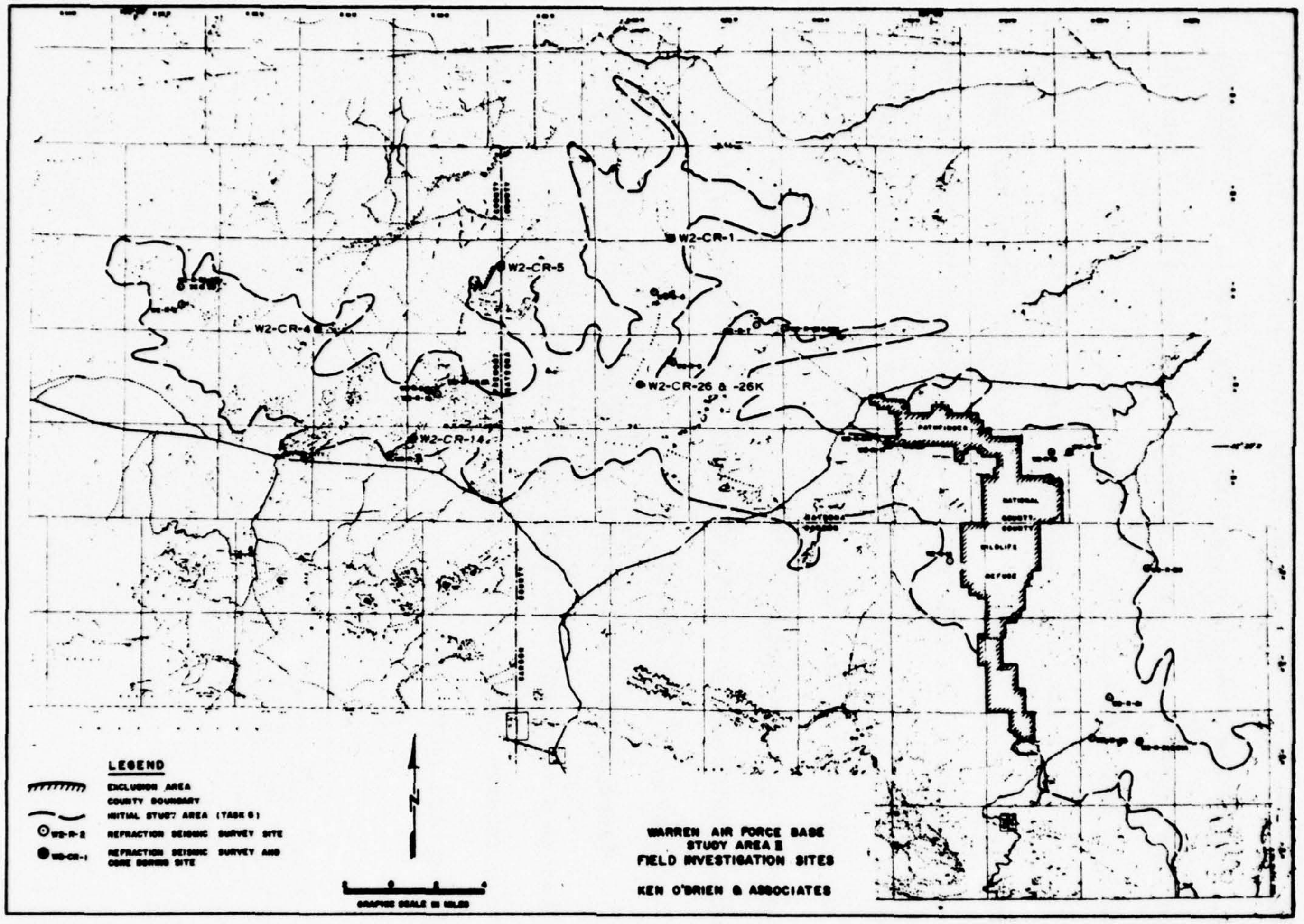
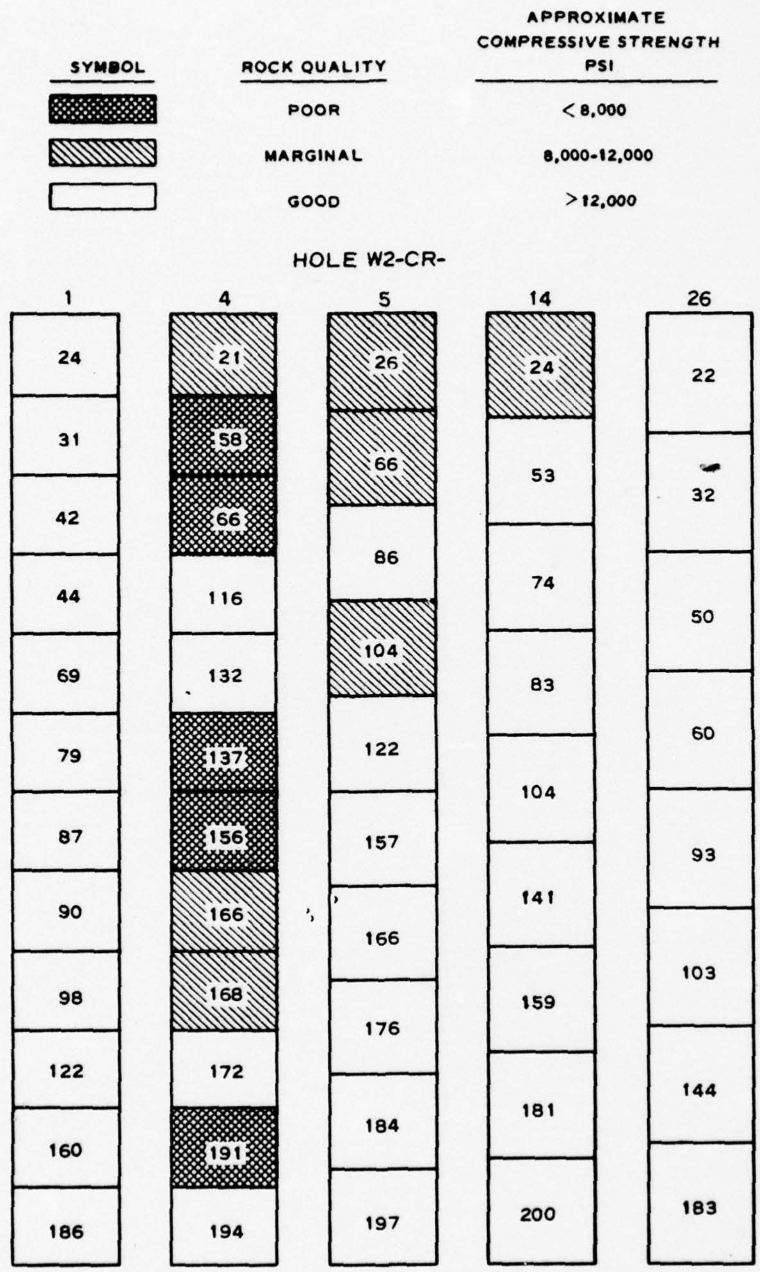


Figure 5.1 Field investigation sites.



NOTE: INDIVIDUAL NUMBERS WITHIN BLOCKS INDICATE DEPTHS OF TEST SPECIMENS.

Figure 5.2 Depth versus quality for individual holes.

APPENDIX A

DATA REPORT

Hole W2-CR-1

21 August 1969

Hole Location: Natrona County, Wyoming

Township 32N, Range 88W, Section 35

900' W/EL, 650' N/SL, SE 1/4 SE 1/4

Core

1. The following core was received on 4 August 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	5
2	24
3	31
4	42
5	44
6	54
7	59
8	69
9	79
10	87
11	90
12	98
13	107
14	116
15	122
16	130
17	142
18	149
19	151
20	160
21	168
22	178
23	186
24	192
25	196
26	200

Description

2. The samples received were pink- to white-colored porphyritic granite and gray and white diorite, as identified by the field log received with the core. Piece Nos. 1 and 2 appeared somewhat weathered. Piece Nos. 5, 8, 10, 11, 13, 16, 18, and 20 contained fractures, some open, and some incipient.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg. psi	Comp Wave Vel. fps
2	Gray, Fine Grained, Critical Angle Fracture	24	2.764	--	12,420	15,730
3	Gray Diorite, Intact	31	2.736	--	21,210	20,400
4	Pink Granite, Intact	42	2.652	61.8	22,580	20,705
5	Gray Diorite, Vertical Incipient Fracture	44	2.729	61.1	18,180	20,610
8	Pink Granite, Vertical Incipient Fracture	69	2.655	63.2	31,060	20,760
9	Pink Granite, Intact	79	2.767	61.4	25,000	20,730
10	Pink Granite, Vertical Incipient Fracture	87	2.639	60.8	35,760	20,850
11	Pink Granite, Fine Grained, Vertical Incipient Fracture	90	2.635	--	48,180	20,435
12	Pink Granite, Intact	98	2.649	--	28,030	20,240
15	Gray Diorite, Intact	122	2.739	59.2	24,240	20,610
20	Pink Granite, Critical Angle Fracture	160	2.671	60.7	13,640	20,055
23	Gray Diorite, Intact	186	2.681	64.2	21,670	20,155
Average of Specimens with Critical Angle Fractures (2)			2.718	60.7	13,030	17,890
Average of All Other Specimens (10)			2.688	61.7	27,590	20,550

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Of the fractured specimens tested, the two containing critical angle fractures failed along these fractures and exhibited significantly lower unconfined compressive strengths. The vertical incipient fracturing appeared to have little affect on physical properties of the material from this hole.

5. All but two of the specimens tested were medium grained. One of the fine grained specimens (No. 2) failed along a critical angle fracture at a comparatively low compressive stress. The other (No. 11) yielded a very high compressive strength, characteristic of fine grained, competent, intact rock.

Moduli of deformation

6. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 2, 10, and 17. Stress-strain curves are given in plates 1, 2, and 3. Specimens 10 and 17 were cycled at 10,000 psi. Results are given below.

Specimen	Modulus, psi x 10^{-6}			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
			Dynamic Tests		
2	8.0	4.9	3.5	9,340	0.23
4	12.6	8.6	5.0	11,860	0.26
5	11.3	9.8	4.4	10,880	0.31
11	12.7	7.9	5.2	12,075	0.23
20	11.9	8.2	4.7	11,470	0.26

(Continued)

(Continued)

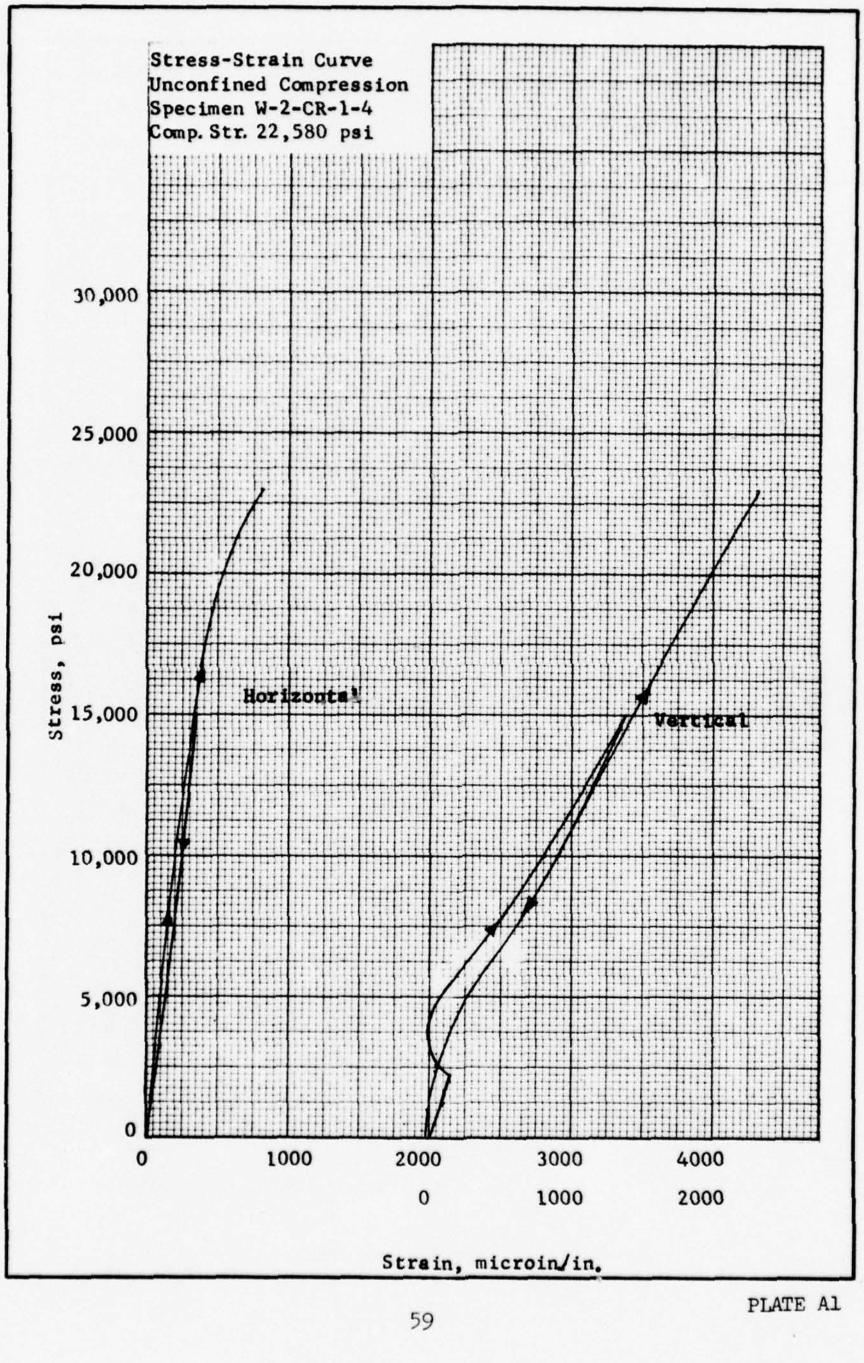
Specimen No.	Modulus, psi x 10^{-6} Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Static Tests			
4	9.2	5.3	3.8	--	0.21
5	9.1	5.1	3.8	--	0.20
11	10.5	6.2	4.3	--	0.22

7. All of the rock tested herein is apparently rather rigid material exhibiting slight hysteresis. The initial erratic behavior of the vertical stress-strain relations for specimen Nos. 4 and 5 was possibly due to location of the vertical gages over a fracture along which lateral displacement occurred during the early stages of loading.

Conclusions

8. The core received for testing from hole W-2-CR-1 was identified as pink-to white-colored porphyritic granite and gray and white diorite by the field log received with the core. Incipient fracturing was present in several specimens, some oriented of critical angles, some vertical. The critical angle fractures significantly weakened the rock; failure occurring along these fractures and of much lower compressive stresses. All other specimens exhibited conical modes of failure, higher compressive strengths, and higher dynamic moduli.

	Specimens With Critical Angle Fractures	All Other Specimens
Specific Gravity	2.718	2.688
Schmidt No.	60.7	61.7
Compressive Strength, psi	13,030	27,590
Compressional Wave Velocity, fps	17,890	20,550
Young's Modulus, psi x 10^{-6}	--	9.6



Stress-Strain Curve
Unconfined Compression
Specimen W-2-CR-1-4
Comp. Str. 22,580 psi
Stress, psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE A1

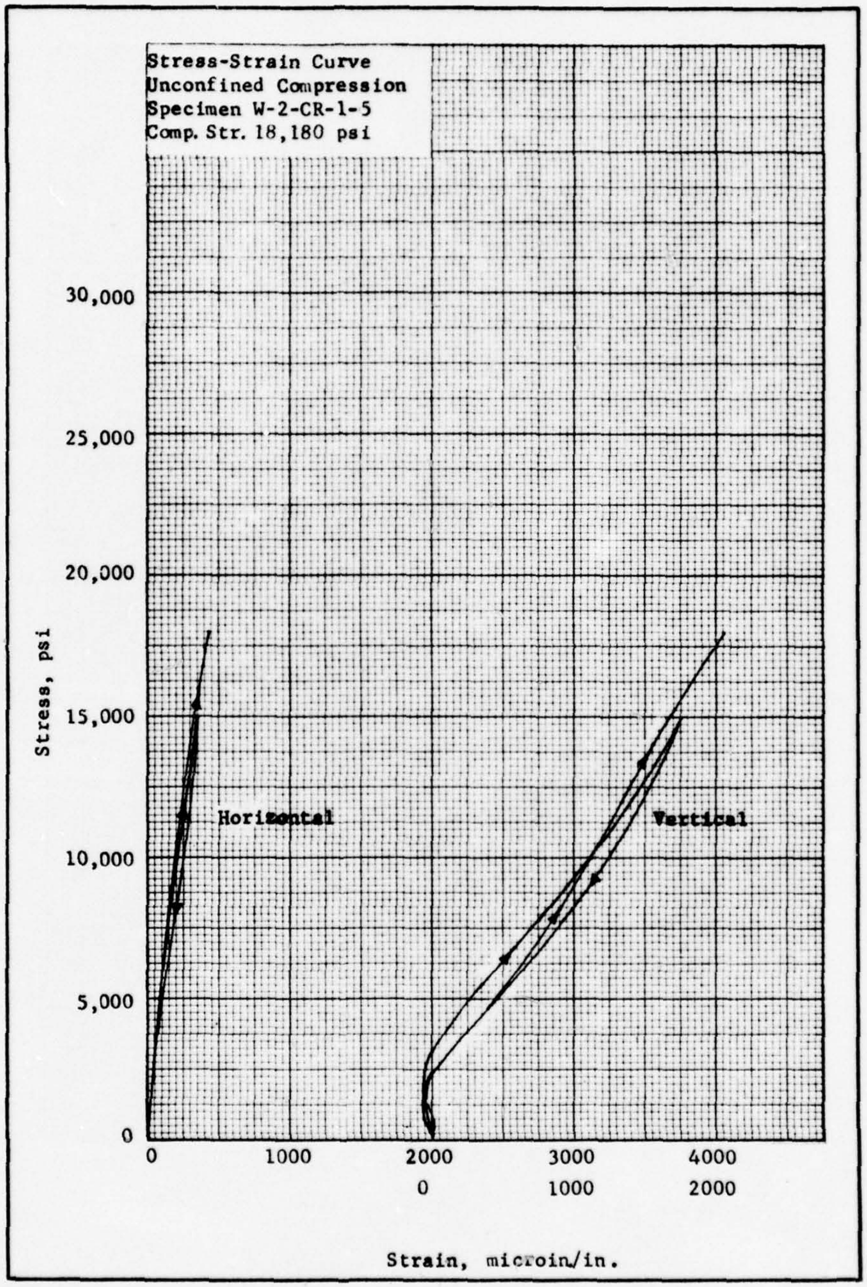

Stress-Strain Curve
Unconfined Compression
Specimen W-2-CR-1-5
Comp. Str. 18,180 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin/in.

PLATE A2

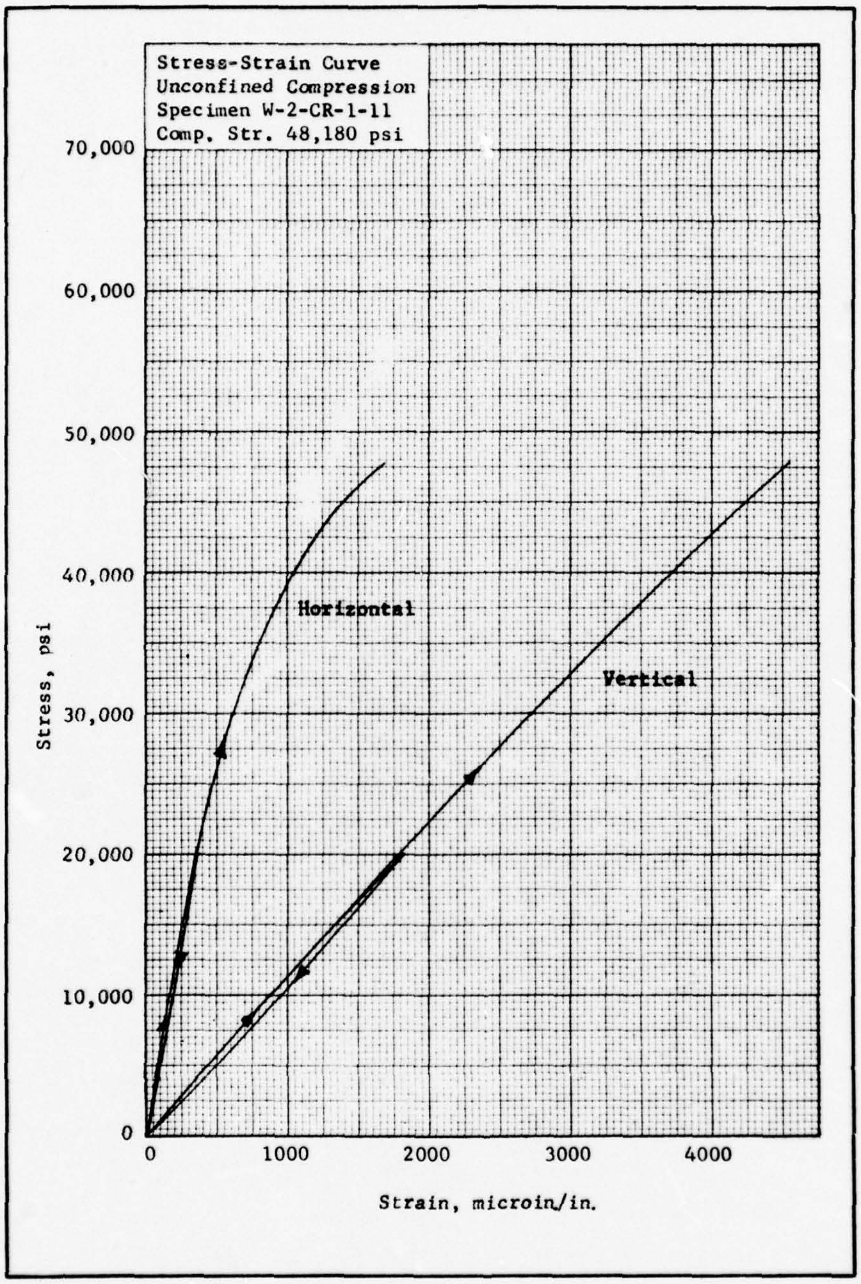

Stress-Strain Curve
Unconfined Compression
Specimen W-2-CR-1-11
Comp. Str. 48,180 psi
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
Strain, microin./in.

PLATE A3

APPENDIX B

DATA REPORT

Hole W2-CR-4

25 August 1969

Hole Location: Fremont County, Wyoming

Township 31N, Range 91W, Section 31

1100' E/WL, 900' N/SL, SW 1/4 SW 1/4

Core

1. The following core was received on 6 August 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	21
2	32
3	40
4	58
5	66
6	68
7	84
8	103
9	109
10	116
11	122
12	132
13	137
14	146
15	156
16	166
17	168
18	172
19	176
20	182
21	191
22	194

Description

2. The samples received were identified by the field log received with the core as granite gneiss, pyroxene hornfels, chlorite-biotite schist, hematite, quartz-porphyry gneiss, and chlorite schist. Piece Nos. 2, 3, 4, 5, 7, 8, 10, 19, 20, and 22 contained fractures, some open and some healed.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Core Log Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
1	Granite Gneiss	21	2.633	55.8	8,405	17,140
4	Chlorite Schist	58	2.906	--	3,505	8,995
5	Chlorite Schist	66	2.858	--	2,800	11,625
10	Pyroxene Hornfels	116	3.024	58.8	25,860	22,715
12	Pyroxene Hornfels	132	3.014	--	19,520	21,865
13	Chlorite-Biotite Schist	137	2.916	14.0	1,210	7,225
15	Chlorite-Biotite Schist	156	3.070	21.8	5,990	11,675
16	Granite Gneiss	156	2.589	--	10,650	16,185
17	Chlorite-Biotite Schist	158	3.095	--	9,170	16,055
18	Quartz-Porphyry Gneiss	172	2.684	--	15,955	18,195
21	Granite Gneiss	191	2.986	43.2	6,240	16,655
22	Granite Gneiss	194	2.670	60.4	25,380	19,795
Average Chlorite Schist (2)			2.882	--	3,150	10,310
Average Pyroxene Hornfels (2)			3.019	58.8	22,690	22,290
Average Granite Gneiss (4)			2.704	53.1	12,670	17,445
Average Chlorite-Biotite Schist (3)			3.027	17.9	5,455	11,650
Average Quartz-Porphyry Gneiss (1)			2.684	--	15,955	18,195

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Due to the large variation of material received from hole W-2-CR-4, the specimens were grouped for testing according to core log descriptions. Physical test results substantiated this grouping, specimens of the same core log description exhibiting similar test results.

5. Generally, the schists exhibited rather low strength, the average for both groups being only 4300 psi. The gneisses and hornfels were considerably stronger, all groups yielding average strengths greater than 10,000 psi. There was, however, considerable variation within groups, some individual specimens being considerably weaker than the average.

Moduli of deformation

6. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 1, 12, and 15. Stress-strain curves are given in plates 1, 2, and 3. Specimens 12 and 15 were cycled at 14,000 and 5000 psi, respectively. Results are given below.

Specimen No.	Modulus, psi x 10^{-6} Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
1	6.6	7.1	2.5	8,320	0.35
5	3.6	3.4	1.4	5,955	0.32
12	13.0	12.9	4.9	10,965	0.33
15	4.8	3.0	2.0	6,870	0.24
17	8.2	6.5	3.2	8,695	0.29

(Continued)

(Continued)

Specimen No.	Modulus, psi x 10^{-6} Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
			Static Tests		
1	6.9	3.1	3.1	--	0.13
12	12.3	6.2	5.3	--	0.17
15	2.0	1.3	0.8	--	0.24

7. Most of the rock tested herein is apparently rather rigid material exhibiting little hysteresis. Specimen No. 15, however, a chlorite-biotite schist, exhibited considerable hysteresis. The hysteresis loops for this specimen remained open, indicating the presence of a relatively large amount of residual strain (950 microin./in.). This specimen exhibited plastic behavior over practically the entire range of loading.

Conclusions

8. The core received from hole W-2-CR-4 was quite variable, identified by the field log received with the core as granite gneiss, pyroxene hornfels, chlorite-biotite schist, hematite, quartz-porphyry gneiss, and chlorite schist. Fracturing was present in some specimens. Generally, physical properties were quite variable, the schists yielding rather low physical properties, the gneisses and hornfels exhibiting strength generally over 10,000 psi.

Property	Chlorite Schist	Pyroxene Hornfels	Granite Gneiss	Chlorite-Biotite Schist	Quartz-Porphyry Gneiss
Specific Gravity	3.882	3.019	2.704	3.027	2.684
Schmidt No.	--	58.8	53.1	17.9	--
Compressive Strength, psi	3,150	22,690	12,670	5,455	15,955
Compressional Wave Velocity, fps	10,310	22,290	17,445	11,650	18,195
Young's Modulus, psi x 10^{-6}	--	12.3	6.9	2.0	--

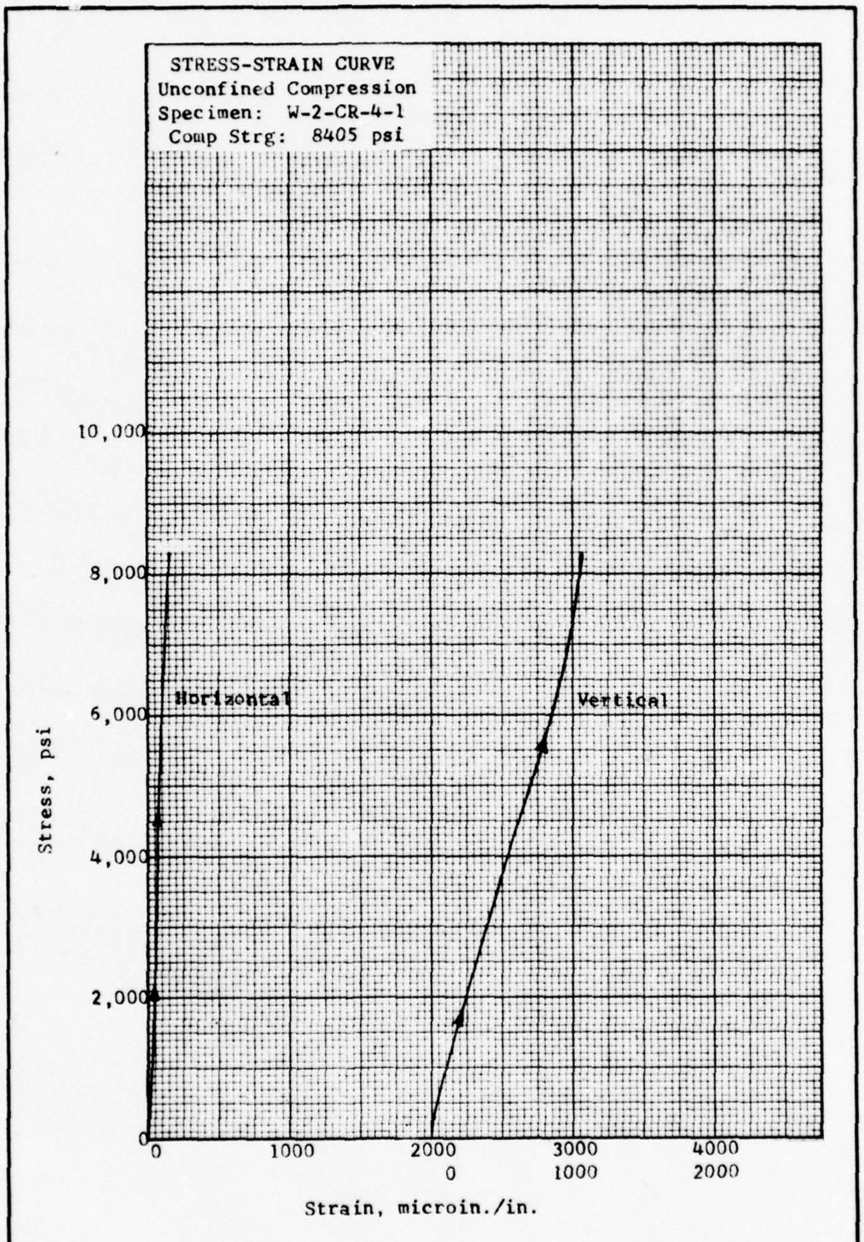

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-4-1
Comp Strg: 8405 psi
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE B1

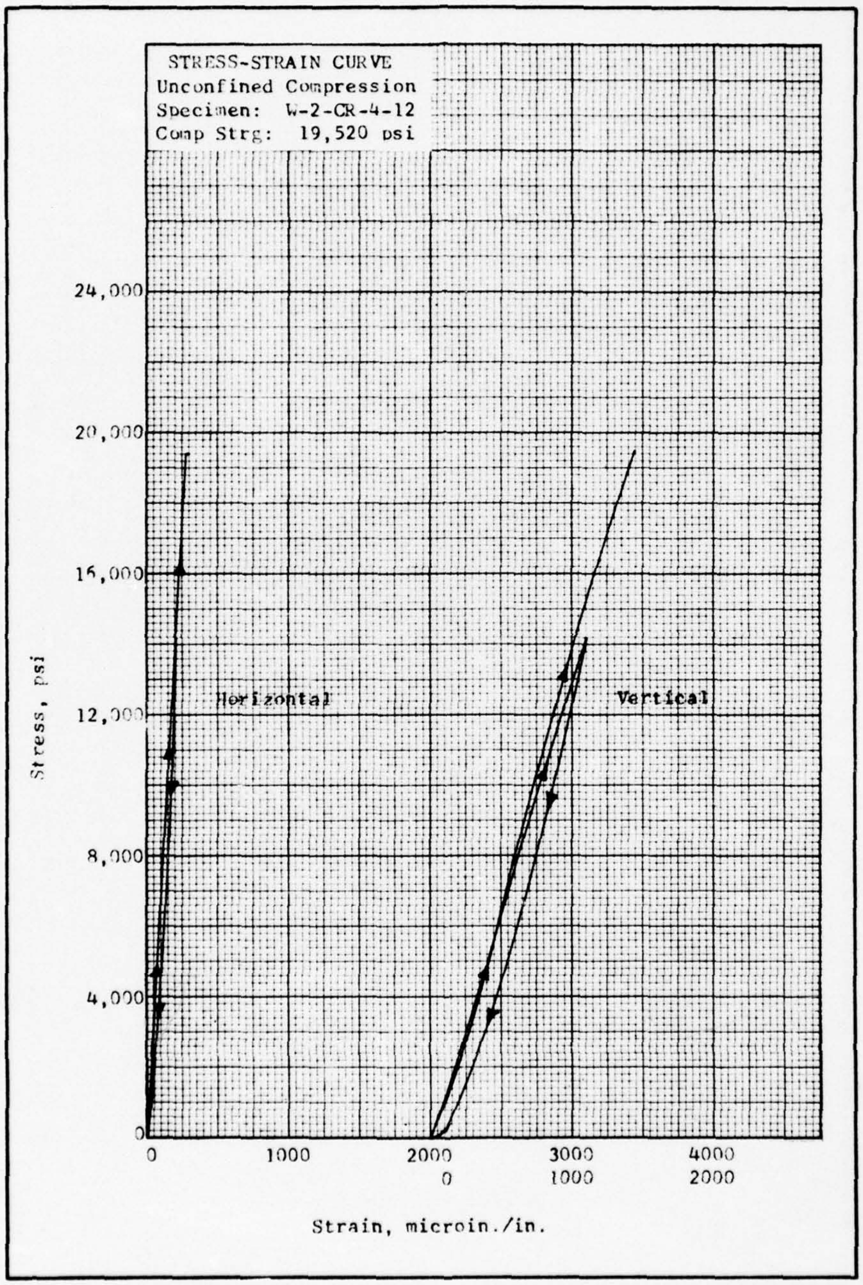
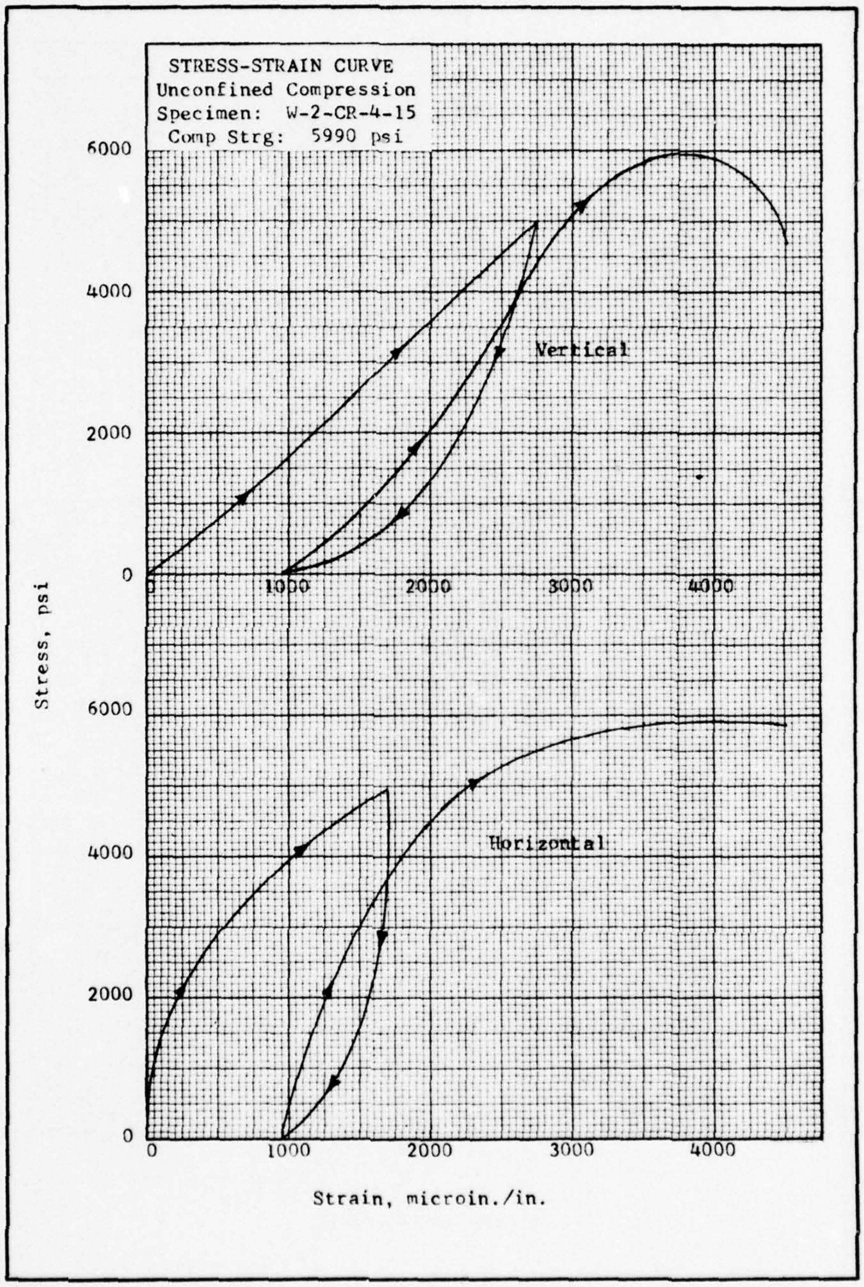

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-4-12
Comp Strg: 19,520 psi
24,000
20,000
16,000
12,000
8,000
4,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE B2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-4-15
Comp Strg: 5990 psi
Stress, psi
Vertical
Horizontal
Strain, microin./in.
0
2000
4000
6000
1000
3000

PLATE B3

APPENDIX C

DATA REPORT

Hole W2-CR-5

26 August 1969

Hole Location: Fremont County, Wyoming

Township 31N, Range 90W, Section 12

900' W/EL, 950' N/SL, SE 1/4 SE 1/4

Core

1. The following core was received on 6 August 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	14
2	26
3	37
4	39
5	50
6	57
7	66
8	71
9	86
10	96
11	104
12	112
13	118
14	122
15	130
16	137
17	146
18	157
19	166
20	176
21	184
22	197

Description

2. The samples received were gray- to black-gray-colored rock identified as quartz-biotite gneiss and quartz-mica gneiss by the field log received with the core. Piece Nos. 1, 3, 11, 15, 16, 19, and 20 contained fractures, most of which were tightly closed.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
2	Quartz Biotite Gneiss	26	2.655	32.1	**	**
7	Quartz Biotite Gneiss	66	2.670	57.8	11,515	19,300
9	Biotite Gneiss	86	2.677	60.8	20,480	18,505
11	Gneiss	104	2.704	46.8	10,940	17,205
14	Biotite Gneiss	122	2.726	45.6	22,090	18,095
18	Biotite Gneiss, Medium Grained	157	2.691	--	22,120	19,820
19	Biotite Gneiss, Vertical Fractures	166	2.691	57.2	18,180	19,945
20	Biotite Gneiss, Vertical Fractures	176	2.728	--	12,550	19,430
21	Biotite Gneiss, Coarse Grained	184	2.732	58.4	21,335	20,235
22	Biotite Gneiss, Coarse Grained	197	2.703	56.3	16,300	20,085
Average of All Specimens Tested			2.698	51.9	17,280	19,180

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

** Specimen was broken during determination of compressional wave velocity; compressive strength test was not conducted.

4. The results of unconfined compressive tests were rather variable, probably due to the variation in grain size, foliation, and incipient fracturing. The specimens containing fracturing and planes of foliation oriented at critical angles (Nos. 7, 11, 19, 20, and 22) sheared along these planes. The ultimate stress for these specimens fell somewhat below average.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 7, 11, and 21. Stress-strain curves are given in plates 1, 2, and 3. Specimens 7 and 21 were cycled at 10,000 psi; specimen 11 was cycled at 5000 psi. Results are given below.

Specimen	Modulus, psi x 10^{-6}			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
		Dynamic Tests			
7	10.0	7.6	4.4	11,045	0.26
11	8.5	6.4	3.3	9,535	0.28
21	12.7	8.2	5.1	11,800	0.24
		Static Tests			
7	8.1	3.6	3.6	--	0.12
11	6.6	3.7	2.7	--	0.20
21	10.4	6.2	4.3	--	0.22

All of the rock tested herein is apparently rather rigid material, exhibiting slight hysteresis.

Conclusions

6. The core received for testing from hole W-2-CR-5 was identified as quartz-biotite gneiss and quartz-mica gneiss by the field log received with the core. The specimens were gray to black-gray in color; some fracturing was present. Compressive strengths varied from 10,000 to 22,000 psi, the lower strengths exhibited by specimens which failed along well-developed critical angle planes of foliation or fracturing.

Property	Average of All Specimens Tested
Specific Gravity	2.698
Schmidt No.	51.9
Compressive Strength, psi	17,820
Compressional Wave Velocity, fps	19,180
Young's Modulus, psi x 10^{-5}	8.4

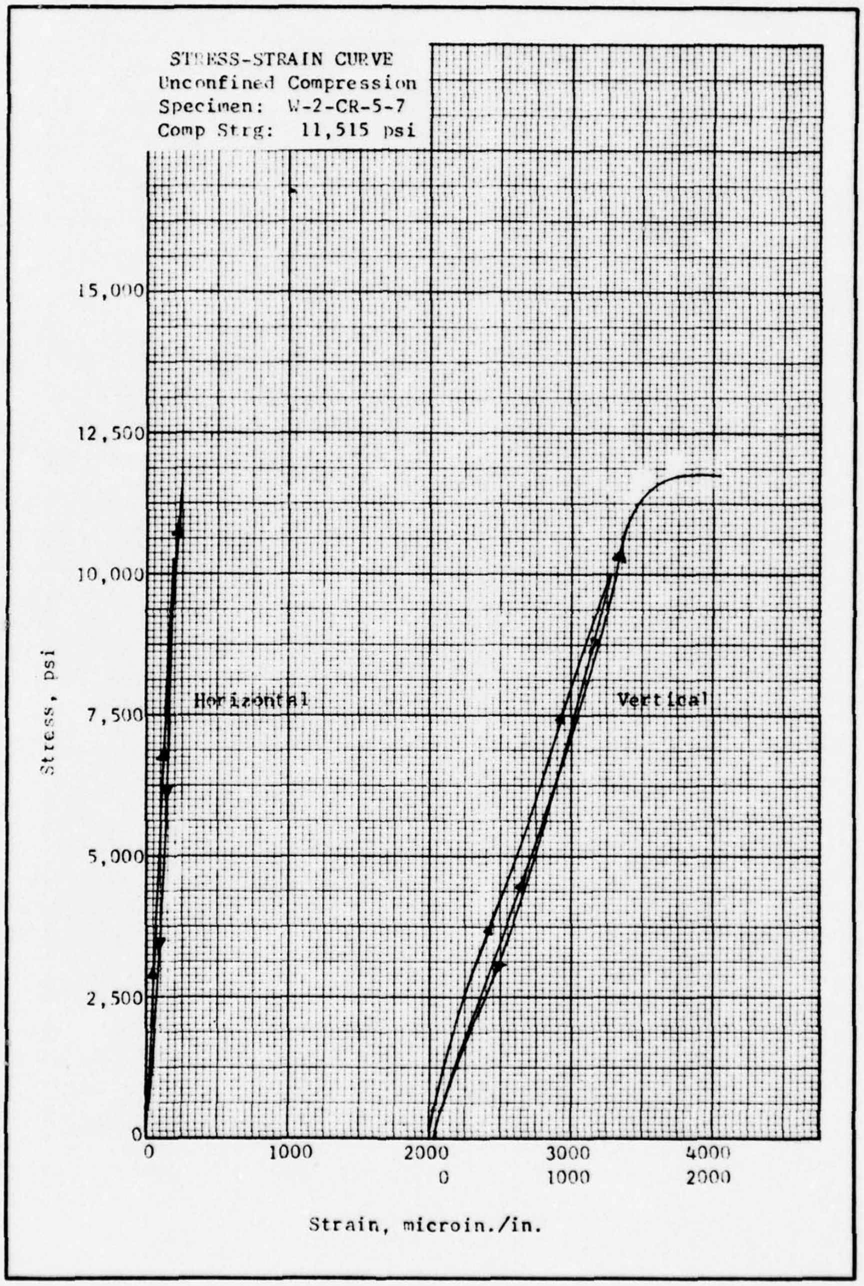

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-5-7
Comp Strg: 11,515 psi
Stress, psi
15,000
12,500
10,000
7,500
5,000
2,500
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE C1

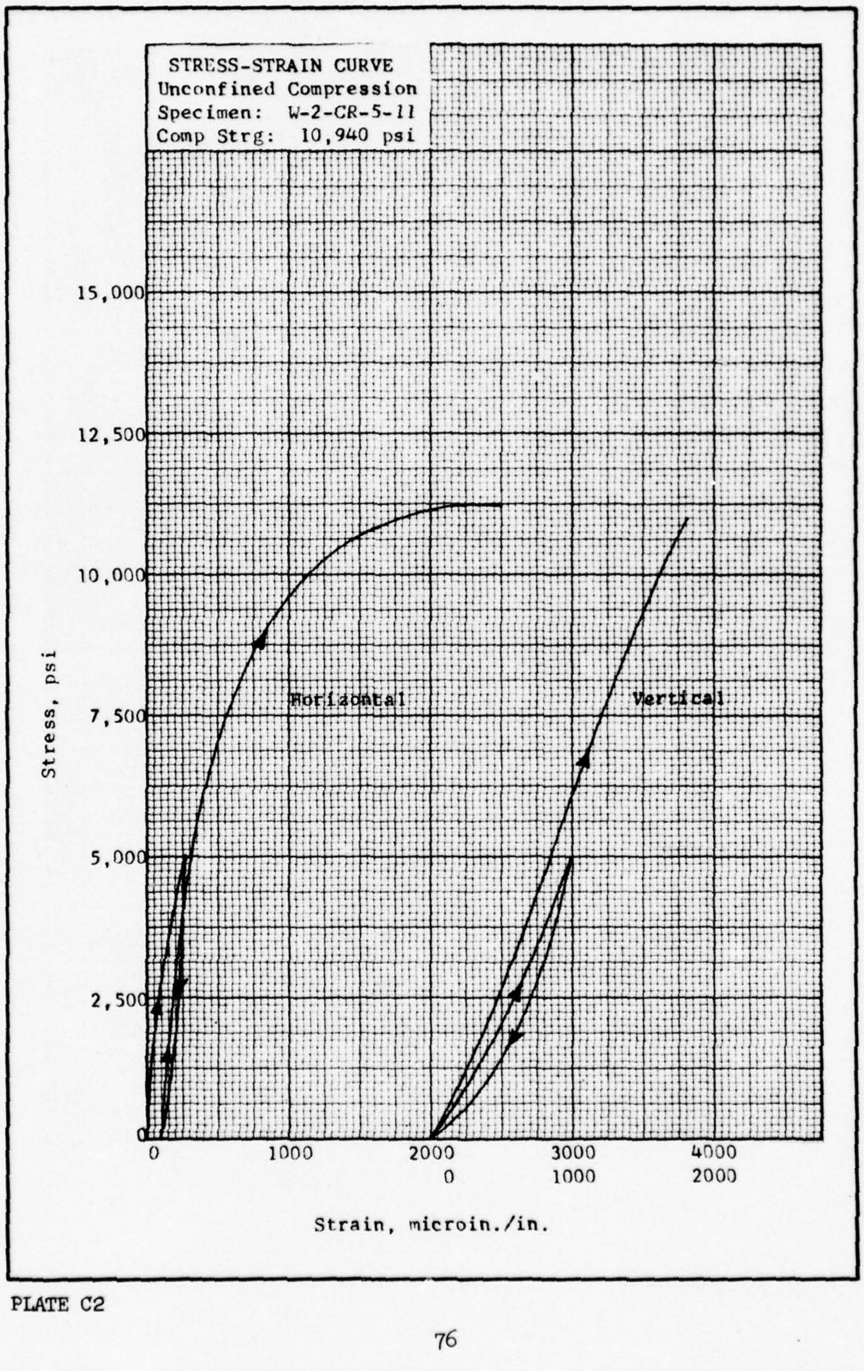
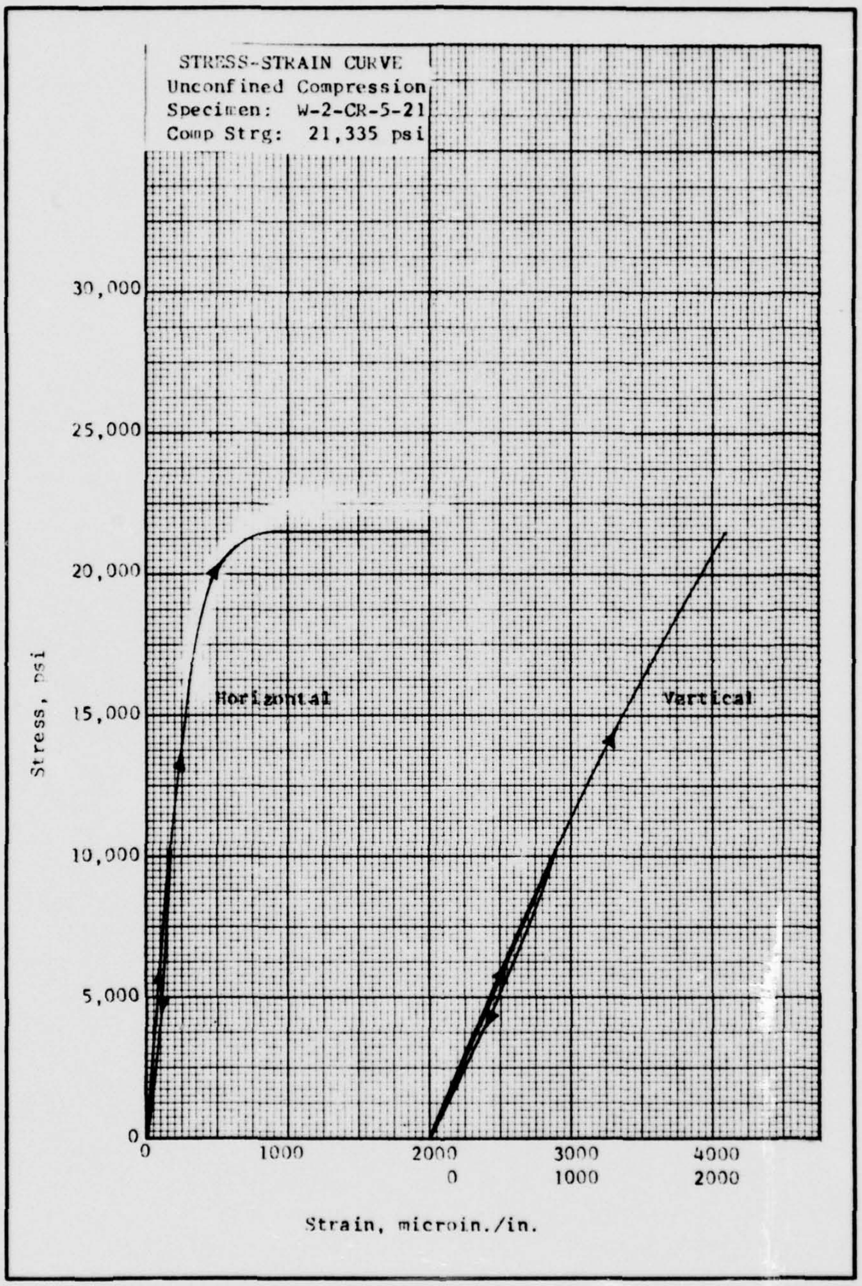

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-5-11
Comp Strg: 10,940 psi
15,000
12,500
10,000
7,500
5,000
2,500
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE C2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-5-21
Comp Strg: 21,335 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
Strain, microin./in.

PLATE C3

APPENDIX D

DATA REPORT

Hole W2-CR-14

28 August 1969

Hole Location: Fremont County, Wyoming

Township 29N, Range 90W, Section 6

1350' E/WL, 800' N/SL, SW 1/4 SW 1/4

Core

1. The following core was received on 14 August 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	24
2	35
3	44
4	44
5	53
6	63
7	74
8	83
9	93
10	104
11	113
12	123
13	134
14	141
15	149
16	159
17	170
18	179
19	181
20	190
21	200

Description

2. The samples received were brown- to gray-colored rock identified as granite by the field log received with the core. Piece Nos. 1 through 7 appeared somewhat weathered.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
1	Moderately Weathered	24	2.620	40.3	11,335	8,590
5	Slightly Weathered	53	2.640	56.6	22,790	18,655
7	Slightly Weathered	74	2.640	--	20,910	18,630
8	Slightly Weathered	83	2.644	56.2	22,515	18,575
10	Slightly Weathered	104	2.644	56.0	21,395	18,425
14	Slightly Weathered	141	2.639	--	17,305	18,875
16	Unweathered	159	2.645	61.3	24,365	18,930
19	Unweathered	181	2.646	60.1	21,880	18,110
21	Unweathered	200	2.641	61.5	23,875	19,140
Weathered Specimen (1)			2.620	40.3	11,335	8,590
Average of Slightly Weathered to Unweathered Specimens (8)			2.642	58.6	21,880	18,665

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

Specimens 8, 10, and 14 were limenite stained. The specimens which sustained slight **weathering** were apparently not significantly different from the unaltered rock.

Moduli of deformation

4. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 5, 10, and 19. Stress-strain curves are given in plates 1, 2, and 3. Specimens 10 and 19 were cycled at 15,000 psi; specimen 5 was cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
			Dynamic Tests		
5	8.7	8.0	3.3	9,630	0.32
10	9.2	7.4	3.5	9,965	0.29
19	10.0	6.3	4.1	10,675	0.23
			Static Tests		
5	7.8	4.8	3.2	--	0.23
10	8.2	5.4	3.3	--	0.25
19	8.9	7.4	3.4	--	0.30

5. All of the rock tested herein is apparently rather rigid material, exhibiting slight hysteresis. The hysteresis loops remained open, indicative of the presence of small amounts of residual strain.

Conclusions

6. The core received for testing from hole W-2-CR-14 was identified as brown to gray granite by the field log received with the core. Some weathering was present in the upper regions of the hole. Test results for the slightly weathered to unweathered material were relatively uniform, compressive strength ranging from 17,305 to 23,875 psi and compressional wave velocity ranging from 18,110 to 19,140 fps. Generally, compressive strength for the unweathered to slightly weathered rock was approximately twice that exhibited by the moderately weathered material. In no instance, however, did compressive strength fall below 10,000 psi.

Property	Moderately Weathered Specimen	Slightly Weathered to Unweathered Specimens
Specific Gravity	2.620	2.642
Schmidt No.	40.3	58.5
Compressive Strength, psi	11,335	21,880
Compressional Wave Velocity, fps	8,590	18,665
Static Young's Modulus, psi x 10^{-6}	--	8.3

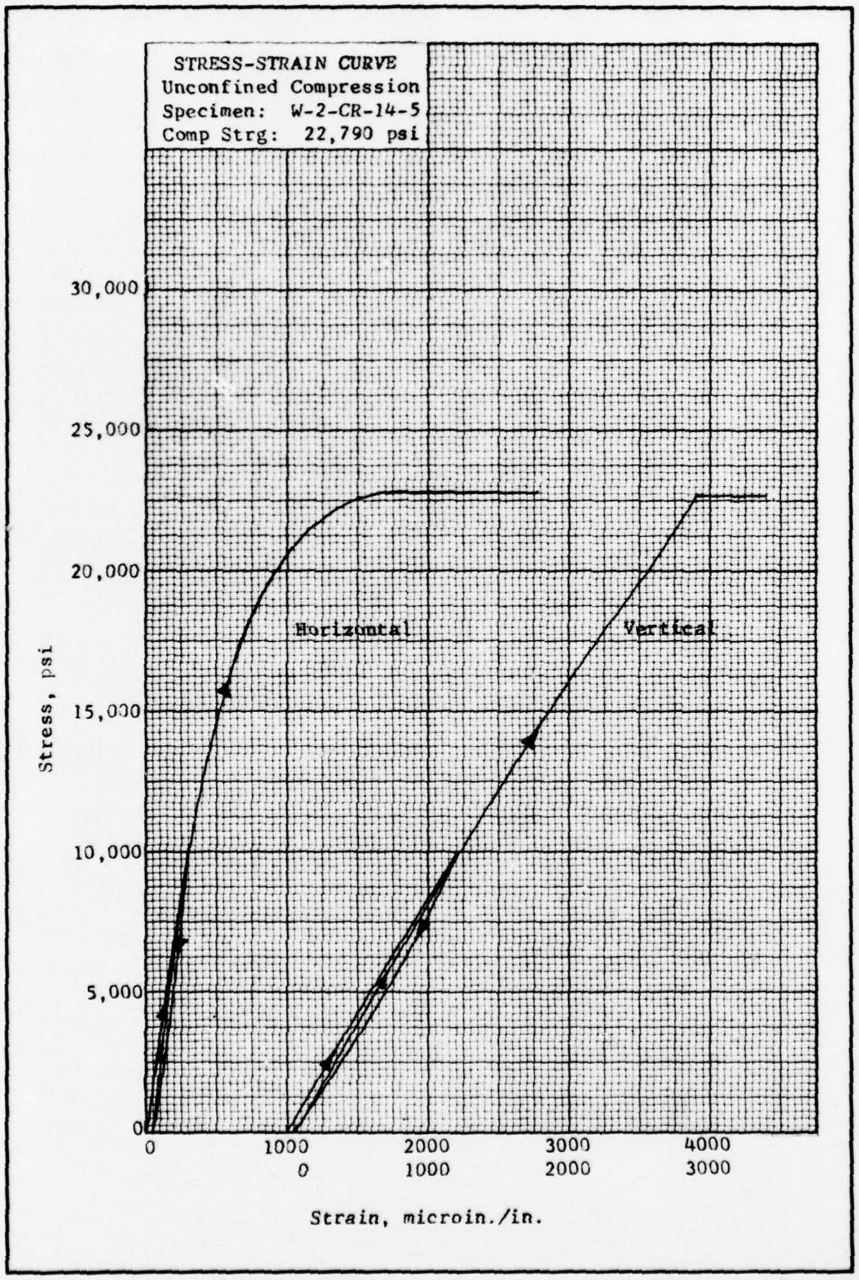
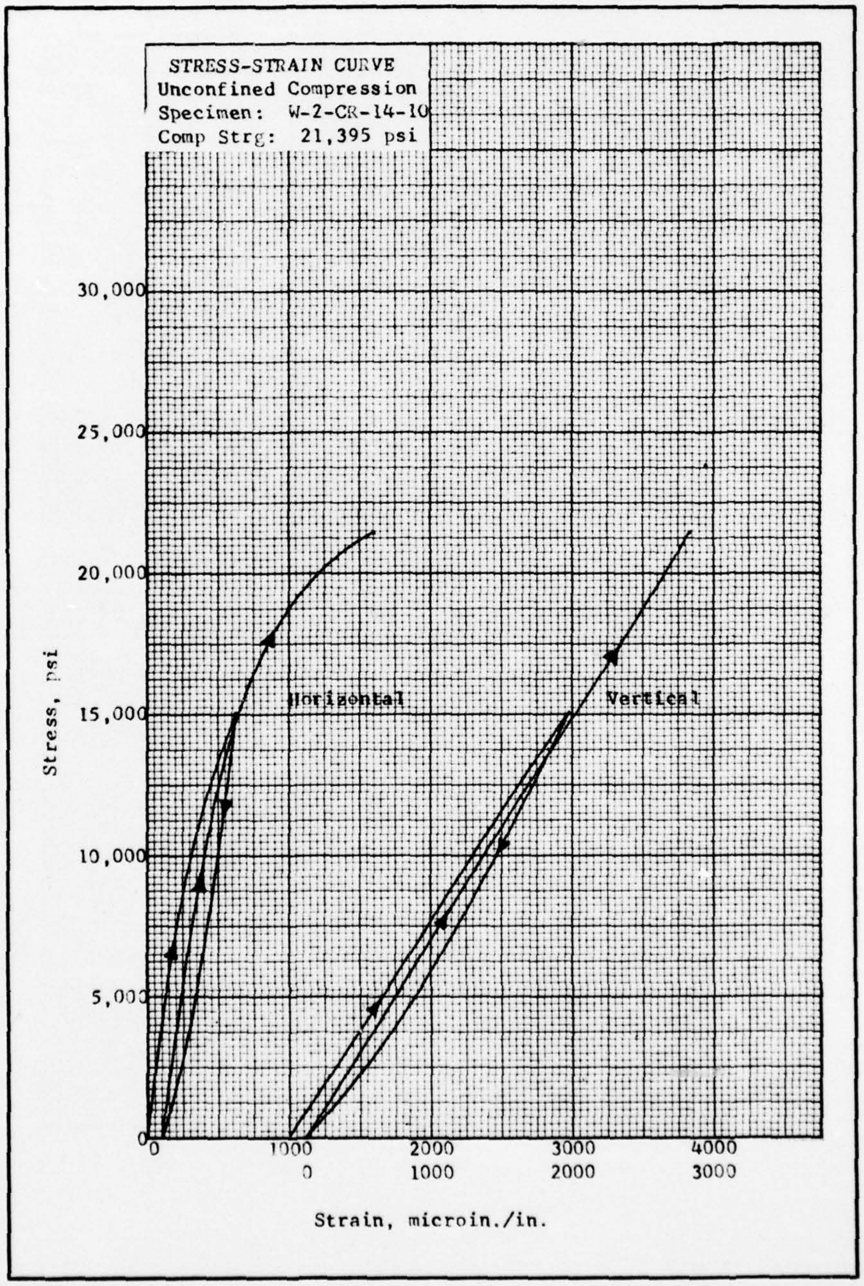

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-14-5
Comp Strg: 22,790 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE D1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-14-10
Comp Strg: 21,395 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE D2

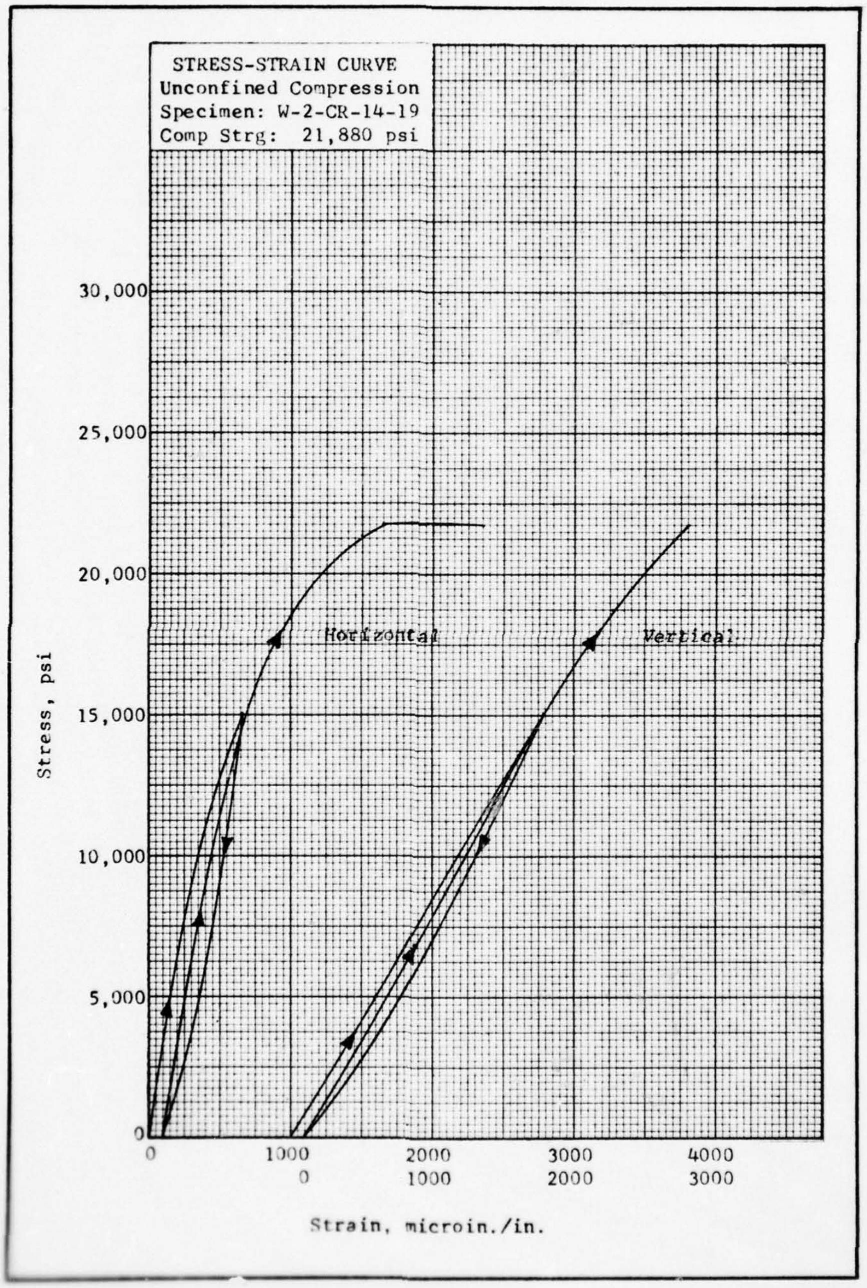

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-14-19
Comp Strg: 21,880 psi
Stress, psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE D3

APPENDIX E

DATA REPORT

Hole W2-CR-26

20 August 1969

Hole Location: Natrona County, Wyoming

Township 30N, Range 88W, Section 21

950' W/EL, 800' S/NL, NE 1/4 NE 1/4

Core

1. The following core was received on 4 August 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	15
2	22
3	32
4	41
5	50
6	60
7	71
8	81
9	93
10	103
11	114
12	124
13	133
14	144
15	154
16	164
17	173
18	183
19	194

Description

2. The samples received were light-gray-colored rock identified as granite by the field log received with the core. Piece Nos. 2 and 3 contained vertical incipient fractures.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
2	Vertical Incipient Fracture	22	2.645	--	28,700	18,225
3	Vertical Incipient Fracture	32	2.668	--	27,270	17,280
5	Intact Rock	50	2.648	52.8	29,700	19,415
6	Intact Rock	60	2.648	49.8	28,790	18,760
9	Intact Rock	93	2.636	48.7	25,230	18,140
10	Intact Rock	103	2.630	48.6	31,670	18,660
14	Intact Rock	144	2.639	49.9	30,075	18,560
18	Intact Rock	183	2.636	49.8	30,160	18,000
Average of All Specimens Tested (8)			2.644	49.9	28,950	18,380

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. The rock from hole W-2-CR-26 was found to be unusually uniform, exhibiting a range in unconfined compressive strength of only 6440 psi with an average strength of 28,950 psi. Apparently, the vertical incipient

fractures in specimen Nos. 2 and 3 had very little, if any, effect on the physical properties of these specimens. Specific gravities, Schmidt numbers, and compressive wave velocities were also relatively uniform for all specimens tested.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 3, 9, and 18. Stress-strain curves are given in plates 1, 2, and 3. Specimens 3, 9, and 18 were cycled at 20,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	9.1	5.9	3.6	10,075	0.24
9	8.3	7.5	3.2	9,440	0.31
18	8.9	6.9	3.4	9,840	0.29
		Static Tests			
3	7.8	4.4	3.2	--	0.21
9	7.1	5.2	2.8	--	0.27
18	8.3	5.6	3.3	--	0.25

6. All of the rock tested herein is apparently rather rigid material exhibiting some hysteresis. The hysteresis loops were not closed, i.e., residual strain was induced in the specimens by the cyclic stressing.

Conclusions

7. The core received for testing from hole W-2-CR-26 was identified as granite by the field log received with the core. All of the core was light-gray colored. Physical tests indicated that the core was unusually uniform, yielding an average unconfined compressive strength of 28,950 psi and a range of only 6440 psi. Vertical incipient fractures in two specimens apparently had no effect on the specimens' physical properties. Both specimens exhibited compressive strengths very close to the average for the group.

Property	Average of All Specimens Tested
Specific Gravity	2.644
Schmidt No.	49.9
Compressive Strength, psi	28,950
Compressional Wave Velocity, fps	18,380
Young's Modulus, psi x 10^5	7.7

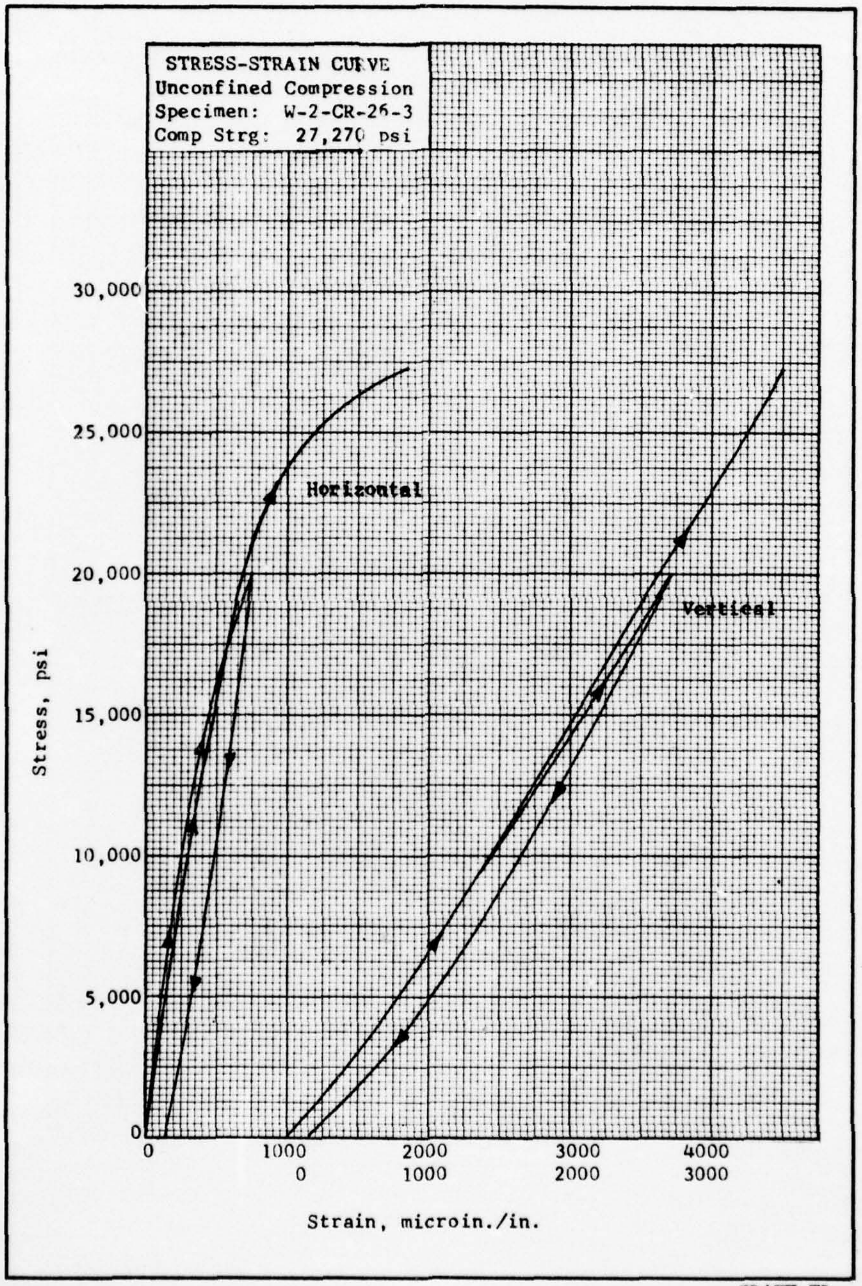
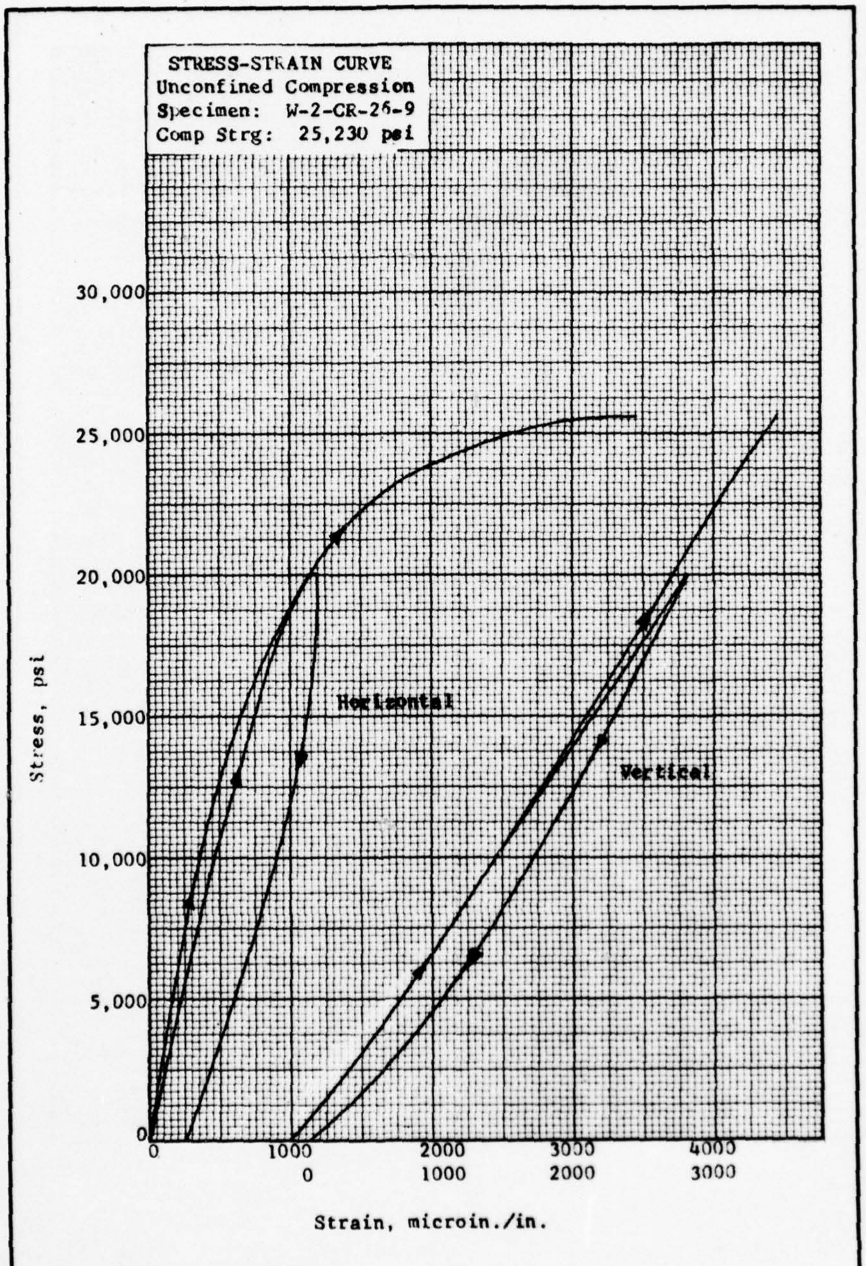

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-26-3
Comp Strg: 27,270 psi
Horizontal
Vertical
Stress, psi
30,000
25,000
20,000
15,000
10,000
5,000
0
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE E1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-26-9
Comp Strg: 25,230 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE E2

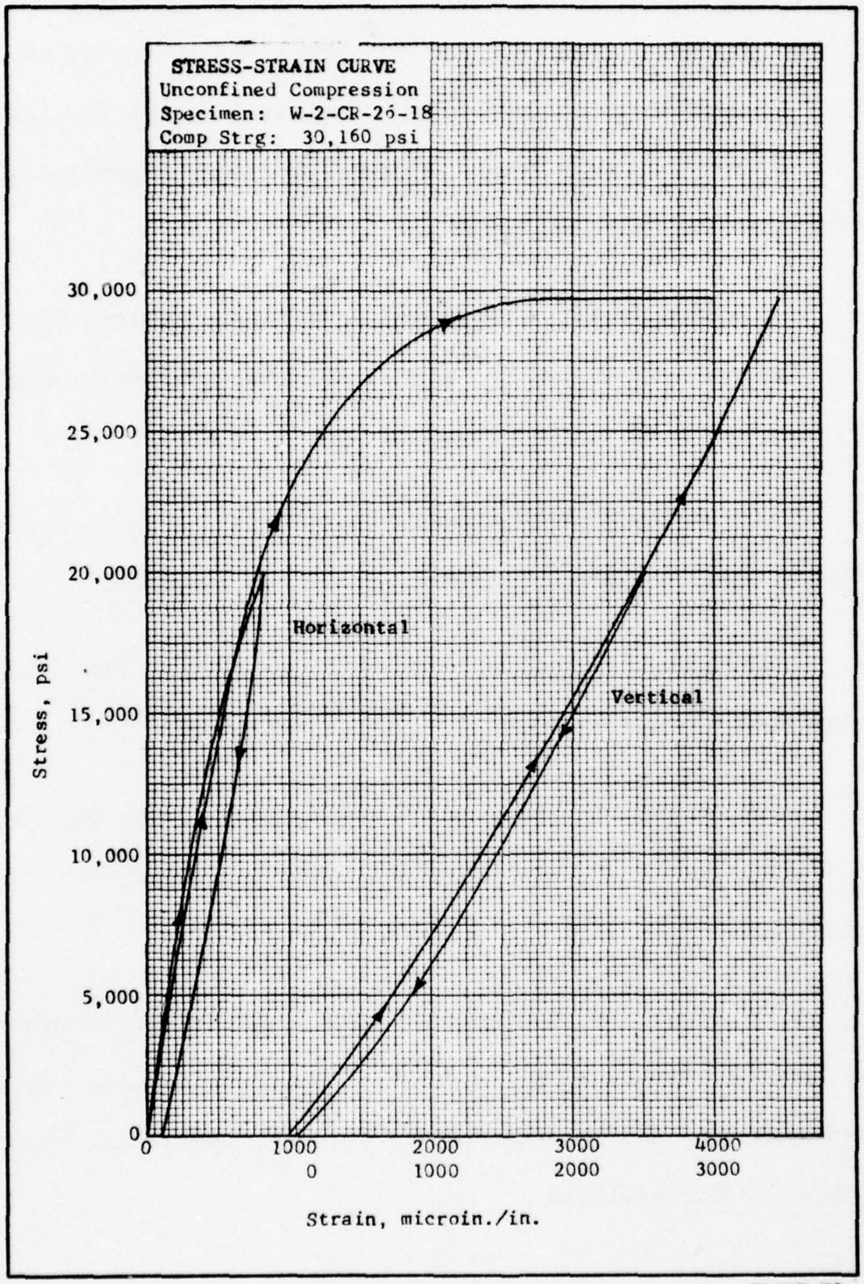

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: W-2-CR-26-18
Comp Strg: 30,160 psi
30,000
25,000
20,000
15,000
10,000
5,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE E3

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13. ABSTRACT

Laboratory tests were conducted on rock core samples received from five holes from Natrona and Fremont Counties, Wyoming (Warren II Study Area). Results were used to determine the quality and uniformity of the rock to depths of 200 feet below ground surface. The rock core was petrographically identified as predominantly granite and biotite gneiss. Several specimens of amphibolite gneiss and biotite schist were also identified. The wide area represented by the five drill holes and the complex nature of the material preclude assessment of the area on a hole-to-hole basis. The overall appearance of the area is one of a complex rock mass with quite variable physical properties. However, based on the limited data available, the area offers possibilities as a competent hard rock medium if poor quality schist can be avoided. Except for the schist, poorer quality rock is predominantly in the upper elevations, but one may expect to remove up to 70 feet of material in some areas before competent rock is reached. A more extensive investigation will be required to identify the most promising hard rock areas.

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